

Bacteria Total Maximum Daily Load Development for Mill Creek, Stony Creek, and the North Fork of the Shenandoah River

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CHAPTER 1: EXECUTIVE SUMMARY

1.1. Background

Three TMDLs are presented in this report: Mill Creek (VAV-B48R-01, 19.78 miles); Stony Creek (VAV-B49R-01, 24.26 miles); and the North Fork of the Shenandoah River (VAV-B45R-04, 52.97 miles). Mill Creek is located in both Rockingham and Shenandoah Counties, while Stony Creek is located entirely within Shenandoah County. The portion of the North Fork of the Shenandoah River that includes the impaired segment (from Turley Creek to Pughs Run) is also located in Rockingham and Shenandoah Counties. Mill and Stony Creek flow into the North Fork of the Shenandoah River, which discharges into the Shenandoah River (USGS Hydrologic Unit Code 02070006), and then flows into the Potomac River; the Potomac River discharges into the Chesapeake Bay.

1.2. Bacteria Impairment

1.2.1. Background

The sum of water quality samples collected on the above stream segments during the 2004 Assessment Period resulted in them being listed as impaired. The interim instantaneous freshwater water quality standard for fecal coliform specifies that fecal coliform concentration in the stream water should not exceed 400 colony forming units (cfu) per 100 mL; the instantaneous standard for *Escherichia coli* specifies that the *E. coli* concentration should not exceed 235 cfu/100 mL. Due to the frequency of water quality violations at the stations listed in

Table 1.1, These impaired segments have been assessed as not supporting the State's Primary Contact Recreational Use Goal. The details of the fact sheet listings are given in Table 1.2.

Table 1.1. Bacteria standard exceedances during the 2004 assessment period (1998-2002).

Station ID	Exceedances of Interim Fecal Coliform Standard
Mill Creek (1BMIL002.20)	11 of 30 (37%)
Stony Creek (1BSTY001.2)	2 of 9 (22%)
North Fork Shenandoah River (1BNFS090.16)	2 of 9(22%)
North Fork Shenandoah River (1BNFS081.42)	10 of 50 (20%)
North Fork Shenandoah River (1BNFS070.67)	9 of 53 (17%)

Table 1.2. Impaired Segments Addressed in this TMDL report.

Impaired Segment	Size	Listing Date	Description	Waterbody Code
Mill Creek	19.78 miles	2004	Discharges into the North Fork Shenandoah River at the Town of Mount Jackson, VA	B48
Stony Creek	24.26 miles	2004	Discharges into the North Fork Shenandoah River at the Town of Edinburg, VA	B49
North Fork Shenandoah River	52.97 miles	2004	Segment of North Fork of the Shenandoah River between Turley Creek to Pughs Run	B42-B50

In order to remedy the fecal coliform water quality impairments, Total Maximum Daily Loads (TMDLs) have been developed, taking into account all sources of bacteria and a margin of safety (MOS). The TMDLs were developed for the new water quality standard for bacteria, which states that the calendar-month geometric mean concentration of *E. coli* shall not exceed 126 cfu/100 mL, and that no single sample can exceed a concentration of 235 cfu/100mL. A glossary of terms used in the development of these TMDLs is listed in Appendix A.

1.2.2. Sources of Bacteria

There are 106 point sources permitted to discharge bacteria into the three watersheds; 12 of these are located in the Mill Creek watershed, 30 in the Stony Creek watershed, and 64 in the North Fork of the Shenandoah River watershed. However, the majority of the bacteria load originates from nonpoint sources. The nonpoint sources of bacteria are mainly agricultural and include land-applied animal waste and manure deposited on pastures by livestock. A significant bacteria load comes from cattle and wildlife directly depositing feces in streams. Wildlife also contribute to bacteria loadings on all land uses, in accordance with the habitat range for each species. Non-agricultural nonpoint sources of bacteria loadings include straight pipes, failing septic systems, and pet waste. The amounts of bacteria produced in different locations (e.g., confinement, pasture, forest) were estimated on a monthly basis to account for seasonal variability in wildlife behavior and livestock production and practices. Livestock management and production factors, such as the fraction of time cattle spend in confinement, pastures, or streams; the amount of manure storage; and spreading schedules for manure application, were considered on a monthly basis.

1.2.3. Modeling

The Hydrological Simulation Program – FORTRAN (HSPF) (Bicknell et al., 2001) was used to simulate the fate and transport of fecal coliform bacteria in the watersheds. As recommended by VADEQ, water quality modeling was conducted with fecal coliform inputs, and then a translator equation was used to convert the output to *E. coli* for the final TMDL. To identify localized sources of fecal coliform within the watersheds, the Mill Creek watershed was divided into 9 sub-watersheds, Stony Creek 20 sub-watersheds, and lower watershed of the North Fork of the Shenandoah River 20 sub-watersheds. The sub-watersheds were delineated based on homogeneity of land use, stream network connectivity, and monitoring station locations.

The hydrology component of HSPF was calibrated using flow data from September 1, 1986 to August 31, 1991; it was validated using data from

September 1, 1991 to August 31, 1995. Both the upper and lower watersheds of the North Fork of the Shenandoah River were calibrated and validated. The lower watershed received inflows from the upper watershed and from the sub-watersheds where previous TMDL plans were developed (Holmans, Linville and Smith Creeks) as point source inputs to the model. Initial estimates of hydrologic parameters were generated according to the guidance in BASINS Technical Note 6 (USEPA, 2000a). These parameters were refined during calibration. The program Expert System for the Calibration of HSPF (HSPEXP) was used to aid in calibration, and after the successful calibration the default calibration criteria in HSPEXP were met for both the calibration and validation periods.

The water quality component of the HSPF model was calibrated for the three impaired watersheds separately, with the inflows from Stony Creek, Mill Creek, the sub-watersheds with previous TMDL plans, and the upper watershed contributing as point source inputs during the calibration of the lower watershed. The upper watershed was calibrated separately from the lower watershed. The bacteria models were calibrated to data from 3 stations for the impaired segments for an approximate time period of 1991 to 2002. Inputs to the model included fecal coliform loadings on land and in the stream. A comparison of simulated and observed fecal coliform loadings in the stream indicated that the model adequately simulated the fate and transport of fecal coliform bacteria.

1.2.4. Margin of Safety

A margin of safety (MOS) was included to account for any uncertainty in the TMDL development process. There are several different ways that the MOS could be incorporated into the TMDL (USEPA, 1991). For Mill Creek, Stony Creek, and Lower North Fork of the Shenandoah River, the MOS was implicitly incorporated into the TMDL by conservatively over estimating several factors affecting bacteria loadings, such as animal numbers, bacteria production rates, and contributions to streams.

1.2.5. Existing Conditions

Contributions from various sources in the watersheds were represented in HSPF to establish the existing conditions for a representative 5-year period that included both low and high-flow conditions. Meteorological data from 1992-1997 were paired with bacterial loading and land use data for existing conditions to establish this baseline scenario. Results from the calibrated HSPF model showed varying contributions to the existing concentrations in Mill Creek, Stony Creek, and the lower watershed of the North Fork of the Shenandoah River watershed, with routine high signatures from livestock direct deposit, wildlife direct deposit, and pervious land surfaces.

1.2.6. TMDL Allocations and Stage 1 Implementation

Monthly bacteria loadings to different land use categories were calculated for each sub-watershed in each watershed for input into HSPF based on amounts of bacteria produced in different locations. Bacteria content of stored waste was adjusted to account for die-off during storage prior to land application. Similarly, bacteria die-off on land was taken into account, as was the reduction in bacteria available for surface wash-off due to incorporation following waste application on cropland. Direct seasonal bacteria loadings to streams by cattle were calculated for pastures adjacent to streams. Bacteria loadings to streams and land by wildlife were estimated for several species. Bacteria loadings to land from failing septic systems were estimated based on number and age of houses. Bacteria contribution from pet waste was also considered.

When developing a bacteria TMDL, the required bacteria load reductions are modeled by decreasing the amount of bacteria applied to the land surface. In the model, this has the effect of reducing the amount of bacteria that reaches the stream, the ultimate goal of the TMDL. Thus, the reductions called for in Table 1.3 in the next section indicate the need to decrease the amount of bacteria reaching the stream in order to meet the applicable water quality standard. The reductions shown are not intended to infer that agricultural producers should reduce their herd size, or limit the use of manures as fertilizer or soil conditioner.

Rather, it is assumed that the required reductions from affected agricultural source categories (cattle direct deposit, cropland, etc.) will be accomplished by implementing BMPs like filter strips, stream fencing, and off-stream watering; and that required reductions from residential source categories will be accomplished by repairing aging septic systems, eliminating straight pipe discharges, and other appropriate measures included in the TMDL Implementation Plan.

For the TMDL allocation scenarios, a target of zero violations of both the instantaneous and geometric mean water quality standards was used. For the Stage 1 implementation scenario, a target of zero reductions in wildlife and 10% violation of the instantaneous standard was used.

1.2.7. Allocation Scenarios

Different source reduction scenarios were evaluated to identify implementable scenarios that meet both the calendar-month geometric mean *E. coli* criterion (126 cfu/100 mL) and the single sample maximum *E. coli* criterion (235 cfu/100 mL) with zero violations. These scenarios were conducted using meteorological data from 1992-1997 to represent a variety of high and low flow conditions. The reductions required for each impaired segment are presented in Table 1.4.

Equation [1.1] was used to calculate the TMDL allocation shown in Table 1.4.

$$\text{TMDL} = \Sigma \text{WLA} + \Sigma \text{LA} + \text{MOS} \quad [1.1]$$

where:

WLA = wasteload allocation (point source contributions);

LA = load allocation (nonpoint source contributions); and

MOS = margin of safety.

Table 1.3. Successful allocation scenarios.

Impaired Watershed	Required Fecal Coliform Loading Reductions to Meet the <i>E. coli</i> Standards,%					
	Cattle DD*	Loads from Cropland	Loads from Pasture	Wildlife DD*	Straight Pipes	Loads from Residential
Mill Creek	85	90	90	50	NA	90
Stony Creek	95	90	90	70	100	90
Lower North Fork Shenandoah River	30	85	85	0	100	85

*DD = direct deposit

The point sources discharge at or below their permit requirements; therefore, the proposed scenario requires load reductions only for nonpoint sources of fecal coliform. The TMDL was determined as the average annual *E. coli* load at the watershed outlet for the chosen allocation scenarios. The WLA was obtained by taking the product of the permitted point source's *E. coli* discharge concentration and allowable annual discharge. The LA is then determined as the TMDL-WLA.

Table 1.4. Annual *E. coli* loadings (cfu/yr) for the TMDLs.

Impaired Segment	ΣWLA	ΣLA	MOS*	TMDL
Mill Creek	0.01×10^{12}	$1,988 \times 10^{12}$	--	$1,988.01 \times 10^{12}$
Stony Creek	4.42×10^{12}	$4,210 \times 10^{12}$	--	$4,214.4 \times 10^{12}$
Lower North Fork Shenandoah River	10.18×10^{12}	$21,734 \times 10^{12}$	--	$21,745 \times 10^{12}$

*Implicit MOS

1.2.8. Stage 1 Implementation

The implementation of a transitional scenario, or Stage 1 implementation, will allow for an evaluation of the effectiveness of management practices and accuracy of model assumptions through data collection. Stage 1 implementation was developed without reductions for wildlife; a target of a 10% violation rate of the single sample *E. coli* water quality standard (235 cfu/100 mL) was used where the elimination of wildlife reductions did not prohibit it.

The Stage 1 scenarios for Mill Creek, Stony Creek, and North Fork of the Shenandoah River are given in Table 1.5.

Table 1.5. Allocation scenarios for Stage 1 implementation for the impaired segments.

Impaired Segment	Single Sample Standard Percent Violation	Required Fecal Coliform Loading Reductions to Meet the Stage 1 Goal, %					
		Live-stock DD	Loads from Cropland	Loads from Pasture	Wildlife DD	Straight Pipes	Loads from Residential
Mill Creek	10	50	50	50	0	NA	50
Stony Creek	10	45	50	50	0	100	50
North Fork Shenandoah River	9	5	15	15	0	100	15

1.3. Reasonable Assurance of Implementation

1.3.1. Follow-Up Monitoring

Following the development of the TMDL, the Department of Environmental Quality (DEQ) will make every effort to continue to monitor the impaired stream in accordance with its ambient monitoring program. DEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with DEQ Guidance Memo No. 03-2004, during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee, and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. At a minimum, the monitoring station must be representative of the original impaired segment. The details of the follow-up monitoring will be outlined in the Annual Water Monitoring Plan prepared by each DEQ Regional Office. Other agency personnel, watershed stakeholders, etc. may provide input

on the Annual Water Monitoring Plan. These recommendations must be made to the DEQ regional TMDL coordinator by September 30 of each year.

DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee, and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants (“water quality milestones” as established in the Implementation Plan), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in DEQ’s standard monitoring plan. Ancillary monitoring by citizens, watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with DEQ monitoring data. In instances where citizens’ monitoring data are not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring managers in each regional office an increase in the number of stations or monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at <http://www.deq.virginia.gov/cmonitor/>.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or TMDL Implementation Plan has been completed), DEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum

requirement is two consecutive samples (one in the spring and one in the fall) in a one year period.

1.3.2. Regulatory Framework

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in attainment of water quality standards. This report represents the culmination of that effort for the bacteria impairment on Mill Creek, Stony Creek, and the lower watershed of the North Fork of the Shenandoah River. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan and to monitor stream water quality to determine if water quality standards are being attained.

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. EPA also requires that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B). All such permits should be submitted to EPA for review.

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). WQMIRA also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR, and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

1.3.3. Implementation Funding Sources

Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". Potential sources for implementation may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program, Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund, tax credits and landowner contributions. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

1.4. Public Participation

Public participation was elicited at every stage of the TMDL development in order to receive input from stakeholders and to apprise the stakeholders of the

progress made. The first public meeting for Mill Creek was May 18, 2005 at St. Andrews Episcopal Church, with 21 people in attendance. The first public meeting for North Fork of the Shenandoah River and Stony Creek was May 25, 2005 at Edinburg Town Hall, with 38 people in attendance. A Local Steering Committee was developed and met three times. The final public meeting was March 21, 2006 at the Shenandoah Co. Parks and Recreation Office in Edinburg, VA. For the final public meeting, the Friends of the North Fork Shenandoah River sent out over 4000 mailings informing watershed residents of the meeting and encouraging them to attend. The mailing also informed watershed residents of what they could do to contribute to the TMDL process. The draft TMDL report was made available to the public for comment on the DEQ website.

CHAPTER 2: INTRODUCTION

2.1. Background

2.1.1. TMDL Definition and Regulatory Information

Section 303(d) of the Federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to identify water bodies that violate state water quality standards and to develop Total Maximum Daily Loads (TMDLs) for such water bodies. A TMDL reflects the total pollutant loading a water body can receive and still meet water quality standards. A TMDL establishes the maximum allowable pollutant loading from both point and nonpoint sources for a water body, allocates the load among the pollutant contributors, and provides a framework for taking actions to restore water quality.

2.1.2. Impairment Listing

Mill Creek is listed as impaired on Virginia's 2004 Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 2004) due to water quality violations of the bacteria standard. The VADEQ has delineated the impairment on Mill Creek on a stream length of 19.78 miles. This segment begins at the headwaters and continues downstream to its confluence with the North Fork of the Shenandoah River.

Stony Creek is listed as impaired on Virginia's 2004 Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 2004) due to water quality violations of the bacteria standard. The Virginia Department of Environmental Quality (VADEQ) has delineated the impairment on Stony Creek on a stream length of 12.13 miles. The impairment includes a 6.48 mile segment between the confluence of Foltz Creek and Little Stony Creek. The impairment also includes a 5.65 mile segment from the George's Chicken discharge to the confluence with the North Fork Shenandoah River.

The North Fork Shenandoah River is listed as impaired on Virginia's 2004 Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 1996) due to water quality violations for the bacteria standard. The Virginia Department of Environmental Quality (VADEQ) has delineated the impairments on the North Fork Shenandoah on a stream length of 52.97 miles. The impaired stream segment begins at its confluence with Turley Creek and continues downstream to its confluence with the Pugh's Run.

2.1.3. Watershed Location and Description

2.1.3a. North Fork Shenandoah

A part of the Shenandoah River basin, the North Fork Shenandoah watershed (TMDL ID VAV-B45R-04) is located in Rockingham and Shenandoah Counties, Virginia, and comprises the following watershed IDs: B42, B43, B44, B45, B46, B47, B48, B49, and B50. Of those watersheds, three have existing TMDLs: B46-Linville Creek, B47-Smith Creek, and Holmans Creek (part of B45). A section of B42 lies within West Virginia. The North Fork Shenandoah is loosely bounded by the state boundary to the west and the Massanutten Mountains to the east (Figure 2.1). Harrisonburg lies on the southern boundary and Woodstock is near the northern boundary. The watershed is approximately 454,000 acres in size, excluding the upper watershed (B42). The locations of the watersheds within the larger watershed boundary are shown in Figure 3.2. North Fork Shenandoah is heavily forested (about 61% of the watershed area), followed by agricultural land uses (about 37%), with the remaining area in residential use (about 2%). The watershed flows north and discharges into the Shenandoah River (USGS Hydrologic Unit Code 02070006), which flows into the Potomac River; the Potomac River discharges into the Chesapeake Bay.

2.1.3b. Stony Creek

A part of the North Fork Shenandoah watershed, the Stony Creek watershed (TMDL ID VAV-B49R-03, VAV-B49R-01) is located in Shenandoah County, Virginia, loosely bounded by Appalachian Mountains to the west, and Edinburg to the east (Figure 2.1). The Stony Creek watershed is approximately

72,600 acres in size. Stony Creek is mainly a forested watershed (about 69%) within the Appalachian Mountains into the rolling valley. The remaining 31% of the watershed area is primarily agricultural (29%), with a small area devoted to rural developments (2%). Stony Creek flows east and discharges into the North Fork of the Shenandoah River, which discharges to the Shenandoah River (USGS Hydrologic Unit Code 02070006), which flows into the Potomac River; the Potomac River discharges into the Chesapeake Bay.

2.1.3.c. Mill Creek

A part of the North Fork Shenandoah watershed, the Mill Creek watershed (TMDL ID VAV-B48R-01) is located in Shenandoah and Rockingham Counties, Virginia. The Mill Creek watershed is approximately 29,786 acres in size. Mill Creek is mainly a forested watershed (53%); the remaining 47% of the watershed is primarily agricultural (46%), with a small area devoted to rural developments (1%). Mill Creek flows east and discharges into the North Fork of the Shenandoah River, which discharges to the Shenandoah River (USGS Hydrologic Unit Code 02070006), which flows into the Potomac River; the Potomac River discharges into the Chesapeake Bay.

2.1.4. Pollutants of Concern

Pollution from both point and nonpoint sources can lead to fecal coliform bacteria contamination of water bodies. Fecal coliform bacteria are found in the intestinal tract of warm-blooded animals; consequently, fecal waste of warm-blooded animals contains fecal coliform. Even though most fecal coliform are not pathogenic, their presence in water indicates contamination by fecal material. Because fecal material may contain pathogenic organisms, water bodies with fecal coliform counts are potential sources of pathogenic organisms. For contact recreational activities such as boating and swimming, health risks increase with increasing fecal coliform counts. If the fecal coliform concentration in a water body exceeds state water quality standards, the water body is listed for violation of the state fecal coliform standard for contact recreational uses. As discussed in Section 2.2.2, Virginia has adopted an *Escherichia coli* (*E. coli*) water quality

standard. The concentration of *E. coli* (a subset of the fecal coliform group) in water is considered to be a better indicator of pathogenic exposure than the concentration of the entire fecal coliform group in the water body.

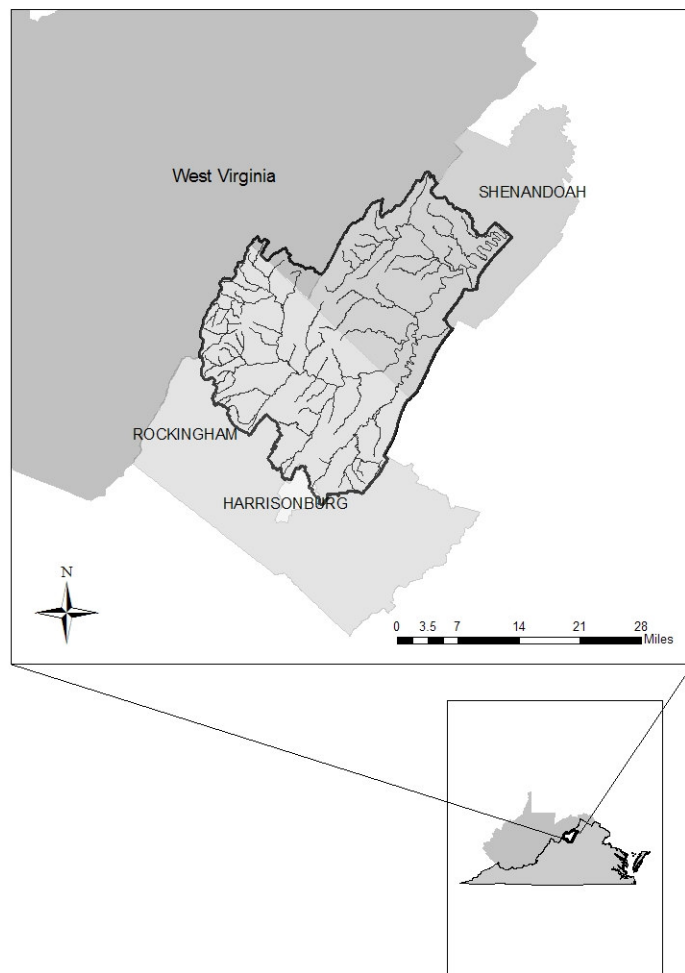


Figure 2.1. Location of North Fork Shenandoah watershed.

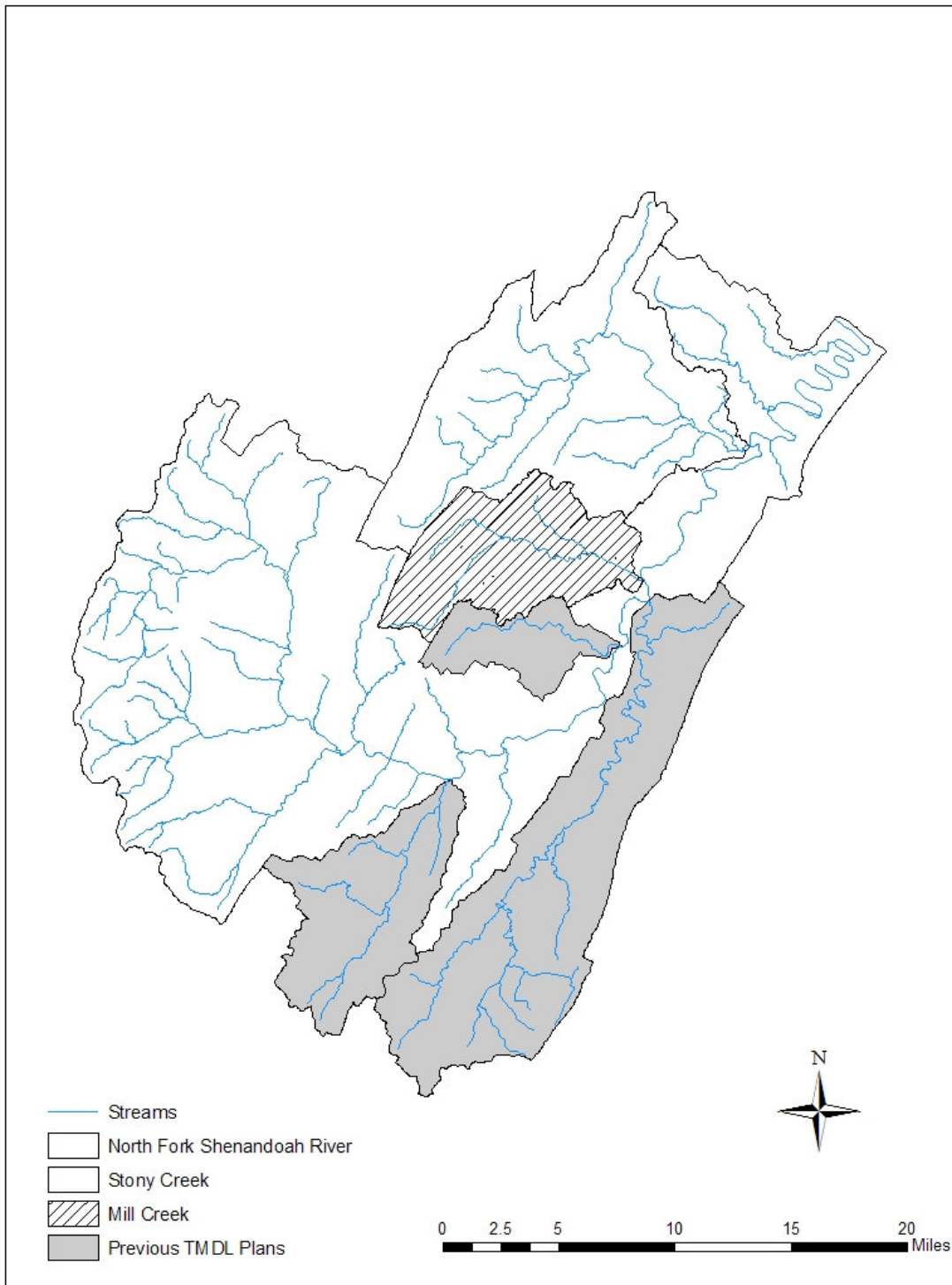


Figure 2.2. Locations of North Fork of the Shenandoah River (B45), Stony Creek, and Mill Creek.

2.2. Designated Uses and Applicable Water Quality Standards

2.2.1. Designation of Uses (9 VAC 25-260-10)

“A. All state waters are designated for the following uses: recreational uses (e.g. swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish).” SWCB, 2002.

North Fork Shenandoah, Stony Creek, and Mill Creek do not support the recreational (swimming) designated use due to violations of the bacteria criteria.

2.2.2. Bacteria Standard (9 VAC 25-260-170)

EPA has recommended that all States adopt an *E. coli* or enterococci standard for fresh water and enterococci criteria for marine waters, because there is a stronger correlation between the concentration of these organisms (*E. coli* and enterococci) and the incidence of gastrointestinal illness than there is with fecal coliform. *E. coli* and enterococci are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals and are subsets of the fecal coliform and fecal streptococcus groups, respectively. In line with this recommendation, Virginia adopted and published revised bacteria criteria on June 17, 2002. The revised criteria became effective on January 15, 2003. As of that date, the *E. coli* standard described below applies to all freshwater streams in Virginia. Additionally, prior to June 30, 2008, the interim fecal coliform standard must be applied at any sampling station that has fewer than 12 samples of *E. coli*.

For a non-shellfish water body to be in compliance with Virginia’s revised bacteria standards (as published in the Virginia Register Volume 18, Issue 20) the following criteria shall apply to protect primary contact recreational uses (VADEQ, 2000):

Interim Fecal Coliform Standard:

Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 mL of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 mL of water.

***Escherichia coli* Standard:**

E. coli bacteria concentrations for freshwater shall not exceed a geometric mean of 126 counts per 100 mL for two or more samples taken during any calendar month and shall not exceed an instantaneous single sample maximum of 235 cfu/100mL.

During any assessment period, if more than 10% of a station's samples exceed the applicable standard, the stream segment associated with that station is classified as impaired and a TMDL must be developed and implemented to bring the station into compliance with the water quality standard. The original impairments to North Fork Shenandoah, Stony Creek, and Mill Creek were based on exceedences of an earlier fecal coliform standard that included a numeric single sample maximum limit of 1,000 cfu/100 mL. The bacteria TMDL for all three impaired segments will be developed to meet the *E. coli* standard. As recommended by VADEQ, the modeling will be conducted with fecal coliform inputs, and then a translator equation will be used to convert the output to *E. coli*.

Chapter 3: WATERSHED CHARACTERIZATION

3.1. Water Resources

3.1.1. North Fork Shenandoah

The North Fork Shenandoah Watershed is a large watershed (492,903 ac) and was subdivided into 40 sub-watersheds for fecal coliform modeling purposes. Twenty sub-watersheds were located upstream of the impairment (Upper Watershed) while the other 20 sub-watersheds (Lower Watershed) included the impaired segment (Figure 3.1). In Figure 3.1, the sub-watershed numbers go up to 27 for the Lower Watershed. The additional 7 sub-watersheds were “utility” watersheds created for used in the model and aggregated for calculating the bacteria sources due to their small sizes. Sub-watersheds were delineated to serve three purposes: first, to group areas of similar land use characteristics; second, to preserve the continuity of the stream network; and third, to allow model output at sub-watershed outlets corresponding to monitoring station locations. Several tributaries flow into the North Fork Shenandoah River, including 3 watersheds with previously developed TMDLs: Linville Creek, Holmans Creek and Smith Creek. Two additional tributaries, Stony Creek (Section 3.1.2) and Mill Creek (Section 3.1.3), had TMDLs developed in conjunction with North Fork Shenandoah River TMDL. Throughout this TMDL report, information will be presented only for the areas without previously developed TMDLs. Each type of information presented will identify whether it describes the entire North Fork Shenandoah watershed or only one of the impaired areas.

Flow is monitored in the North Fork Shenandoah at two locations: station USGS 01632000 is located in the upland area of the watershed draining an area of 210 mi² with a mean flow of 190.84 cfs; USGS 01634000 is located at the lower end of the watershed and drains an area of 768 mi² with a mean flow of

582.38 cfs (Figure 3.2). The lower North Fork Shenandoah watershed area in Figure 3.1 and Figure 3.2 is larger than that shown in Figure 2.2 to allow the watershed model to be developed with output at the hydrology gage located at the outlet of the extended watershed.

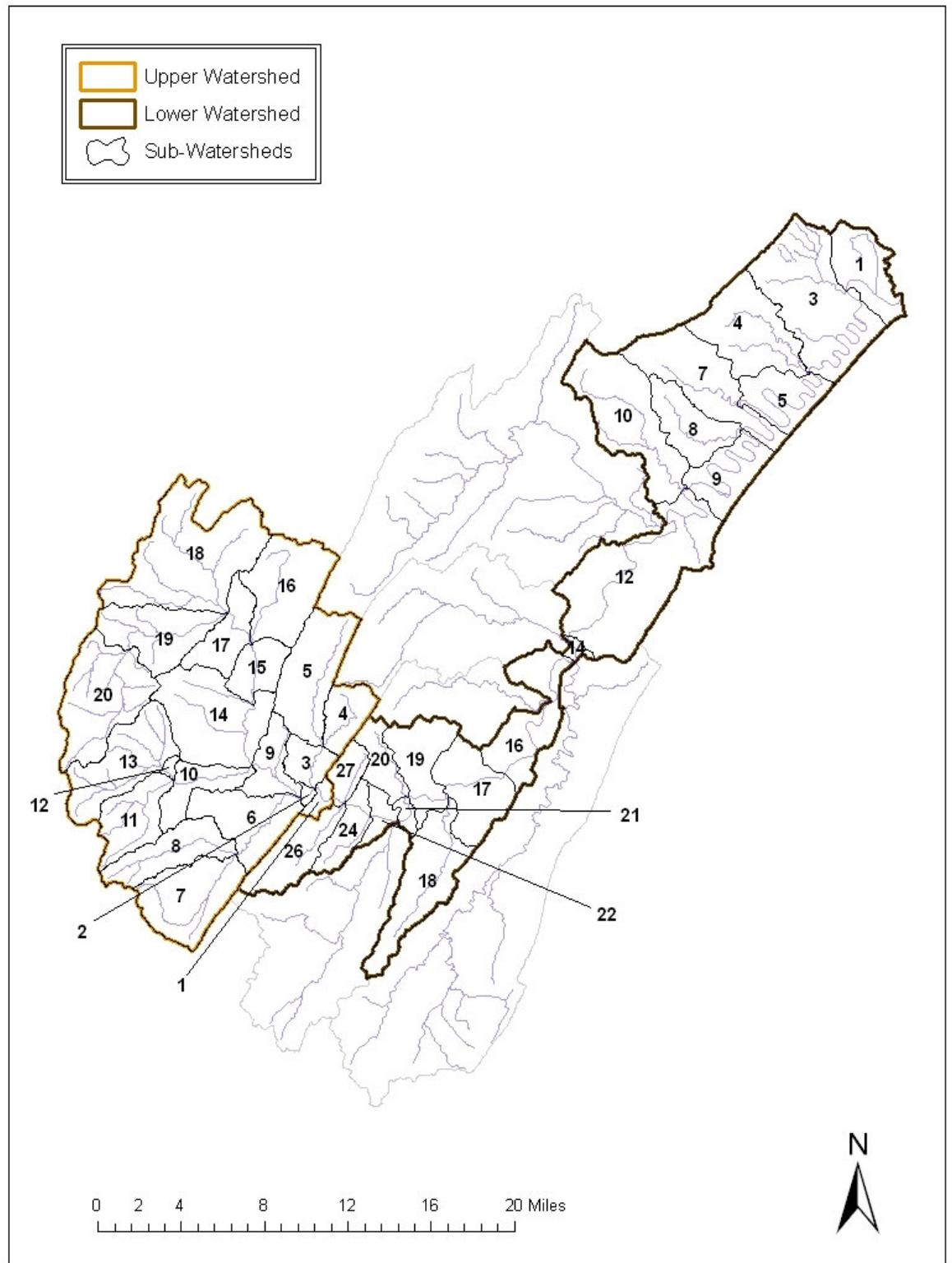


Figure 3.1. Upper and Lower North Fork Shenandoah Sub-Watersheds.

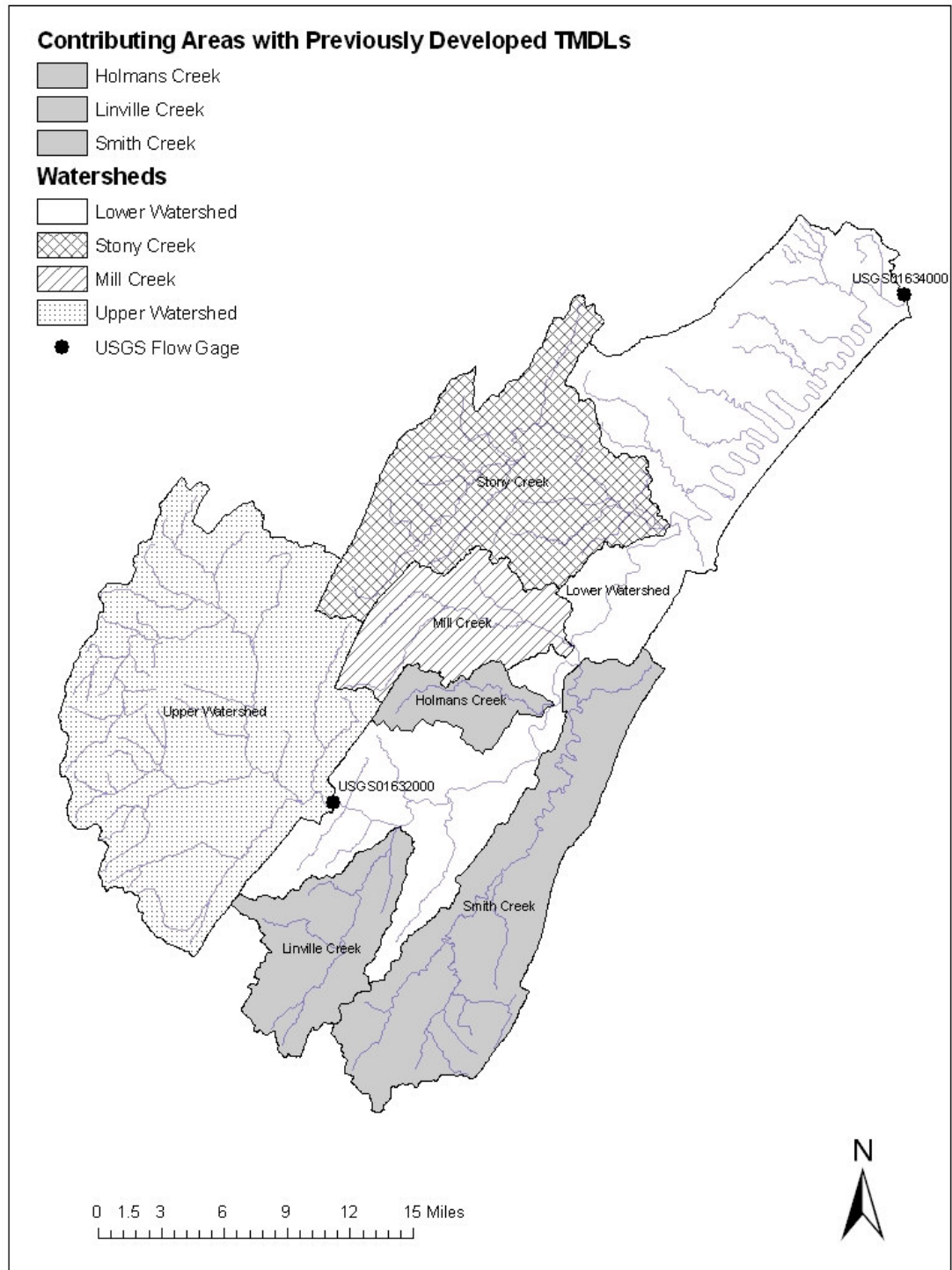


Figure 3.2. TMDL watersheds within the entire North Fork Shenandoah River watershed; solid shading indicates the existence of a previously developed bacteria TMDL.

Twenty-two dams have been identified along the lower North Fork Shenandoah Watershed. These dams are summarized in Table 3.1.

Table 3.1. Location of Dams in the North Fork Shenandoah Watershed

Description of Dam	Longitude (UTM)	Latitude (UTM)
Cootes Store Concrete Dam	686904.17	4278489.23
Strickler's Mill Dam	692989.23	4277534.90
Grim's Mill Dam	695681.15	4278454.04
Concrete Remains of Dam	695469.43	4279097.78
Mill Race Dam	695858.67	4278747.04
Plains Mill Dam	697310.78	4279357.72
Plains Sawmill Dam	698278.85	4279849.04
Zirkle's Saw Mill Dam	700791.65	4281167.47
Pennybacker's Forge Dam	702699.60	4282263.73
Circles Mills Dam	702080.08	4283482.30
Neff's Mill	703180.89	4284777.67
Dam at Cabinet Shop	705239.61	4291265.98
Natural spring side dam	709956.10	4298122.18
Edinburgh Dam 13 ft	713088.12	4300619.14
Chapman Dam Hydro Plant	717024.89	4302806.54
Burnshire Hydro Plant Dam	719727.42	4305978.97
Stonewall Mill Dam	718520.50	4308565.80
Farmer's Mill crib dam	721153.07	4308671.10
Remains of dam and grist mill	727455.47	4315343.87
Concrete dam	727622.24	4318403.61
Manassas Gap concrete dam	730822.70	4317131.86
Manassas Gap concrete dam2	730726.97	4317326.13

Local Aquifers in the North Fork Shenandoah watershed include the Edinburg formation (364EDBG), Beekmantown Group (367BKMN), and Conococheague formation (371CCCG).

3.1.2. Stony Creek

The Stony Creek Watershed was subdivided into 20 sub-watersheds for fecal coliform modeling purposes (Figure 3.3). Sub-watersheds were delineated to serve three purposes: first, to group areas of similar land use characteristics; second, to preserve the continuity of the stream network; and third, to allow model output at sub-watershed outlets corresponding to monitoring station locations. The main branch of Stony Creek runs for 26.47 miles from the headwaters until it enters the North Fork Shenandoah River. Several tributaries

feed into Stony Creek: Riles Run, Swover Creek, Little Stony, Beetle Run, Barb Run, Laurel Run, Falls Run, and Foltz Creek.

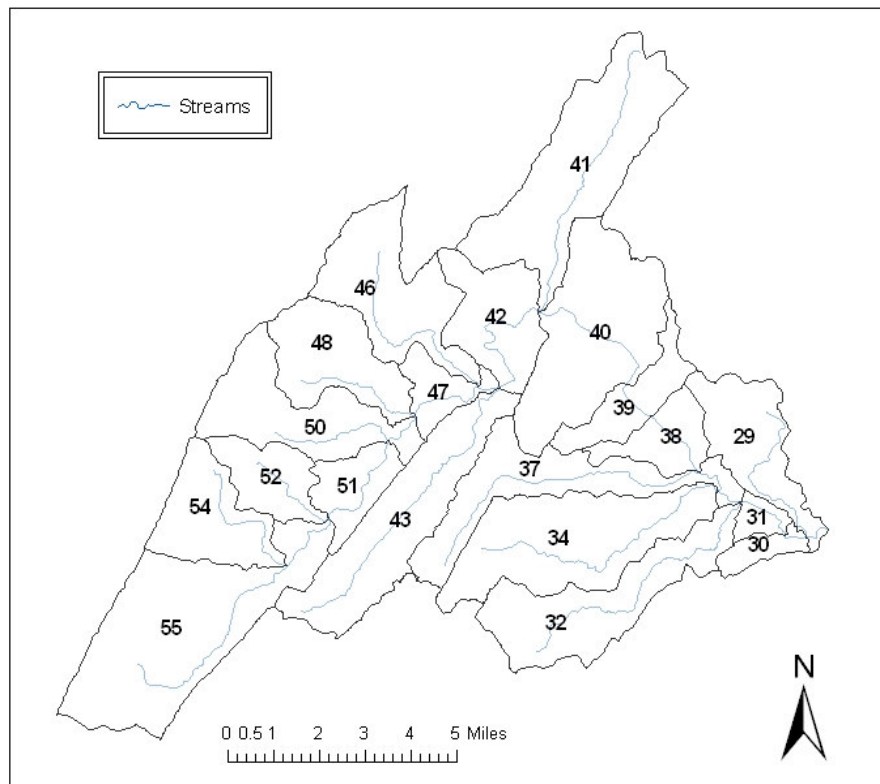


Figure 3.3. Stony Creek Sub-Watersheds

3.1.3. Mill Creek

The Mill Creek Watershed was subdivided into 9 sub-watersheds for fecal coliform modeling purposes (Figure 3.4). Sub-watersheds were delineated to serve three purposes: first, to group areas of similar land use characteristics; second, to preserve the continuity of the stream network; and third, to allow model output at sub-watershed outlets corresponding to monitoring station locations. The main branch of Mill Creek runs for 14.99 miles from the headwaters until it enters the North Fork Shenandoah River. Mill Creek has two major tributaries: Crooked Run, entering 2.90 miles upstream from the confluence with the North Fork Shenandoah and Straight Run, entering 7.60 miles upstream from the confluence with the North Fork Shenandoah.

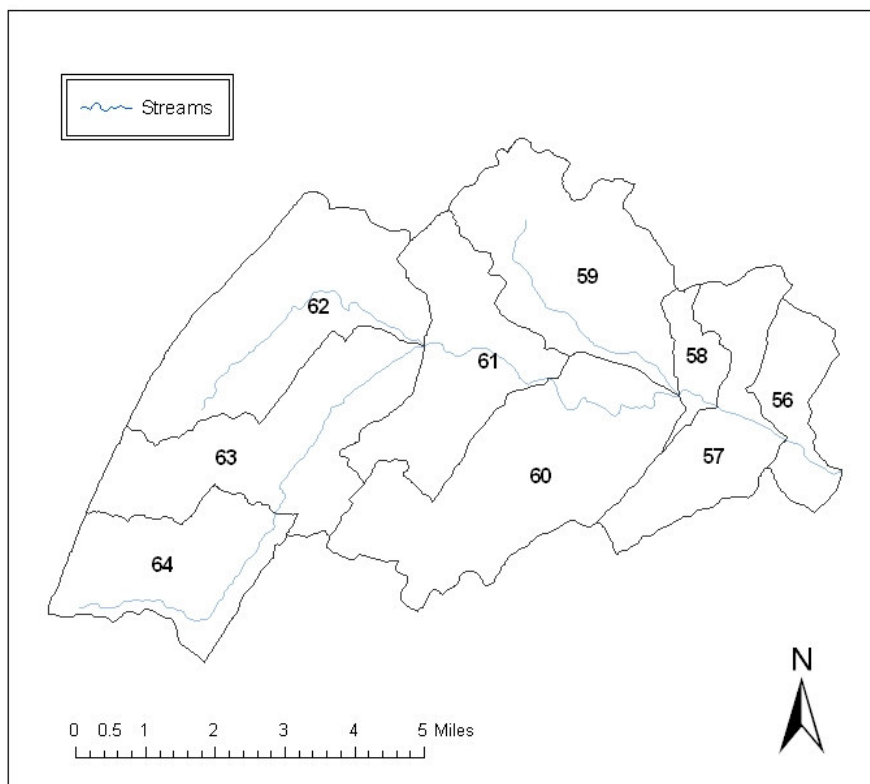


Figure 3.4. Mill Creek Sub-Watersheds

3.2. Ecoregion

The North Fork Shenandoah Watershed is located entirely within Level III Ecoregion 67, which is the Central Appalachian Ridge and Valley region. Level IV ecoregions consist of Northern Limestone/Dolomite Valleys and Northern Shale Valleys bordered by Northern Sandstone Ridges to the northwest and southeast and Northern Dissected Ridges and Knobs to the southwest. The Ridge and Valley Ecoregion is characterized by its generation from a variety of geological materials. The Level III Ecoregion has numerous springs and caves. The ridges tend to be forested, while limestone valleys are composed of rich agricultural land (USEPA, 2002). The Northern Limestone/Dolomite Valleys Level IV ecoregion has fertile land and is primarily agricultural. Steeper areas have scattered forests composed mainly of oak trees. Streams tend to flow year-round and have gentle slopes (Woods et al., 1999). The Northern Shale Valleys Level IV ecoregion is used mainly for farming with woodlands occurring on the

steeper slopes. The Northern Sandstone Ridges Level IV ecoregion is characterized by wooded ridges and extensive forest cover. The Northern Dissected Ridges and Knobs Level IV ecoregion has a similar forest community to the Northern Sandstone Ridges yet it is morphologically distinct being characterized by shale barrens and broken ridges (Woods et al., 1999). The Stony Creek Watershed consists of Northern Limestone/Dolomite Valleys in the east, Northern Sandstone Ridges to the North and West, and Northern Shale Valleys in the center and South. The Mill Creek Watershed consists mainly of Northern Limestone/Dolomite Valleys and Northern Shale Valleys with a very small section of Northern Sandstone Ridges in the southwest corner.

3.3. Soils and Geology

The soils were grouped together based on their location and description in the Shenandoah and Rockingham County Soil Surveys (SCS 1991; SCS 1982) (Table 3.2). The predominant soil units found in the North Fork Shenandoah watershed are the Berks-Weikert associated soils, characterized by shallow to very deep, gently sloping to very steep, well-drained soils with loamy subsoil. These units are found running southwest to northeast along the outer edges of the watershed. The second most prominent units are characterized as being moderately deep and less steep with clayey subsoil. These units tend to be found on either side of the center of the watershed. The Wallen-Dekalb-Drypond unit is found in areas of higher elevation. All of the general soil map units are found on gently sloping to steep topography and are well drained to excessively drained. (SCS, 1982; Sherwood, 1999; SCS, 1991).

Table 3.2. Statsgo Soil Types in the North Fork Shenandoah Watershed.

Soil Type	Acres	Percentage of Soil Type in Watershed
BERKS-WEIKERT-LAIDIG BERKS-WEIKERT-BEDINGTON	149,331.79	38.9%
CARBO-CHILHOWIE-FREDERICK FREDERICK-CARBO-TIMBERVILLE HAGERSTOWN-DUFFIELD-CLARKSBURG	112,098.88	29.2%
WALLEN-DEKALB-DRYPOND	83,395.17	21.7%
MOOMAW-JEFFERSON-ALONZVILLE	37,905.18	9.9%
MONONGAHELA-CLARKSBURG-ERNEST	652.65	0.2%
DEKALB-HAZLETON-LAIDIG	237.75	0.1%
Total	383,621.43	100.0%

3.4. Climate

The climate of the North Fork Shenandoah watershed was characterized for modeling purposes based on the meteorological observations made by Dale Enterprise (Virginia). The long-term record shows average annual precipitation to be 35.42 in., with 58% of the precipitation occurring during the cropping season (May-October) (SERCC, 2002). Average annual snowfall at Dale Enterprise is 24.5 in., with the highest snowfall occurring during February (SERCC, 2002). Average annual daily temperature is 53.4°F. The highest average daily temperature of 73.6°F occurs in July while the lowest average daily temperature of 32.3°F occurs in January (SERCC, 2002).

3.5. Land Use

From the 1992 National Land Cover Dataset (NLCD) (USGS, 2005), land uses in North Fork Shenandoah River were grouped into five major categories based on similarities in hydrologic features and waste application/production practices (Table 3.3).

Table 3.3. Consolidation of NLCD land use for the entire North Fork Shenandoah River watershed.

TMDL Land Use Category	Impervious/Pervious (Percentage)	NLCD Land Use Categories (Class No.)
Cropland	Pervious (100%)	Row Crops (82)
Pasture	Pervious (100%)	Pasture/Hay (81)
Low Intensity Urban	Pervious (85%) Impervious (15%)	Low Intensity Residential (21) Transitional (33)
High Intensity Urban	Pervious (70%) Impervious (30%)	Commercial/Industrial/Transport (23)
Forest	Pervious (100%)	Open Water (11) Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43) Woody Wetlands (91) Emergent Herbaceous Wetlands (92)

Forest is the main land use category in the North Fork Shenandoah River watershed, comprising 60% of the total watershed area (Figure 3.5). Pasture accounts for about 35% of the watershed area while cropland acreage accounts for about 3%. Low intensity urban developments cover 2% of the total area while high intensity urban covers less than 1% (Table 3.4).

Table 3.4. North Fork Shenandoah Watershed Land Use.

Land Use	Percent of Watershed Land Use	Acres
Forest	59.8%	294,786.58
Pasture/Hay	34.9%	172,172.38
Cropland	2.8%	13,805.17
Low Intensity Urban	1.9%	9,194.29
High Intensity Urban	0.6%	2,944.92
Total	100%	492,903.34

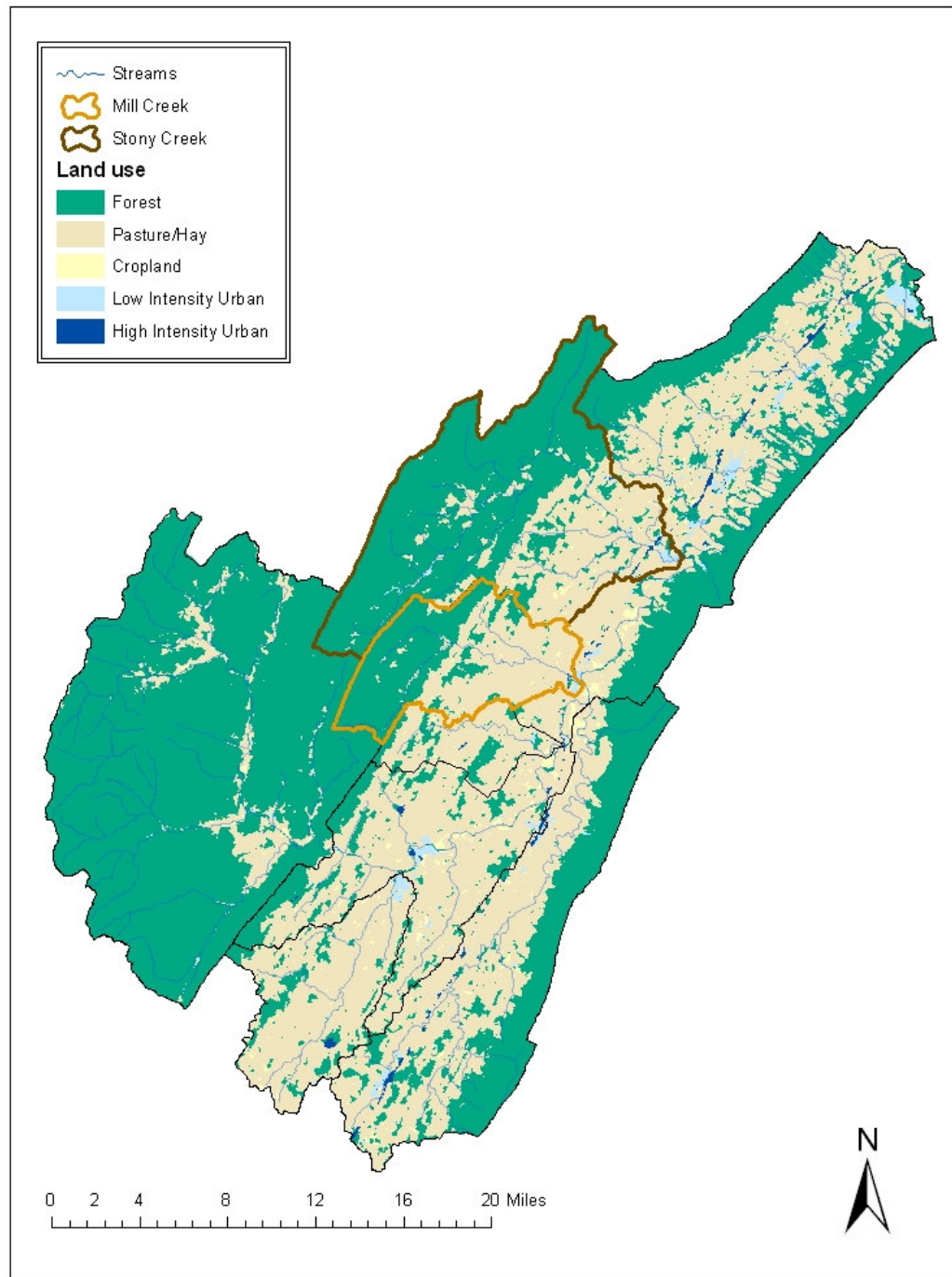


Figure 3.5. North Fork Shenandoah Watershed Land Use Distribution.

Mill Creek follows the same general trend as the North Fork Shenandoah River watershed with forest as the dominant land use (Figure 3.6), 52.9%,

followed by pasture which accounts for an additional 43.6% of the total area. Cropland covers 2.3% of the watershed and low intensity urban covers 1%. High intensity urban is minimal, covering less than 1% of the watershed (Table 3.5). The urban areas are located at the outlet of the watershed, which contains a portion of the town of Mount Jackson.

Table 3.5. Mill Creek Land Use.

Land Use	Percent of Watershed Land Use	Acres
Forest	52.9%	15,763.56
Pasture/Hay	43.6%	12,975.98
Cropland	2.3%	670.93
Low Intensity Urban	1.0%	300.25
High Intensity Urban	0.3%	75.13
Total	100.0%	29,785.84

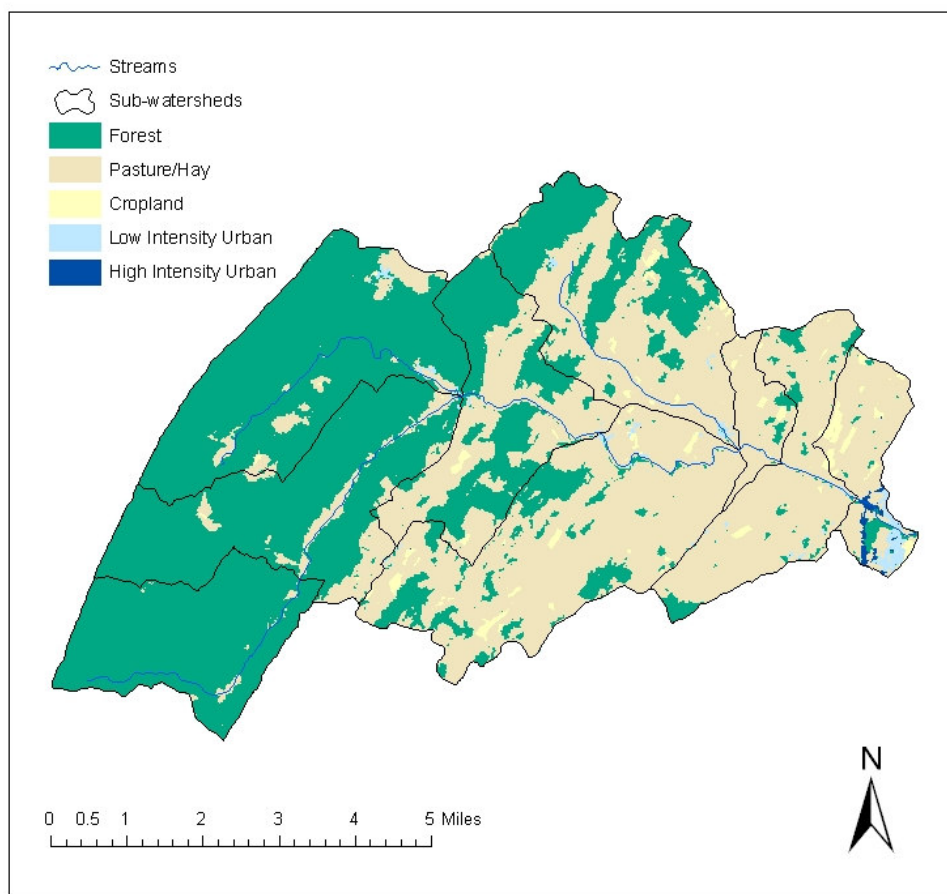


Figure 3.6. Mill Creek Watershed Land Use Distribution.

Stony Creek is comprised mostly of forest land use (Figure 3.7), 77.1%, followed by pasture with 15.9% of the watershed area. Cropland and low intensity urban cover 2.9% and 3.7%, respectively, while high intensity urban covers less than 1% of the watershed area (Table 3.6).

Table 3.6. Stony Creek Land Use.

Land Use	Percent of Watershed Land Use	Acres
Forest	68.8%	49,891
Pasture/Hay	27.6%	20,043
Low Intensity Urban	1.5%	1,090
Cropland	1.8%	1,325
High Intensity Urban	0.3%	213
Total	100%	72,562

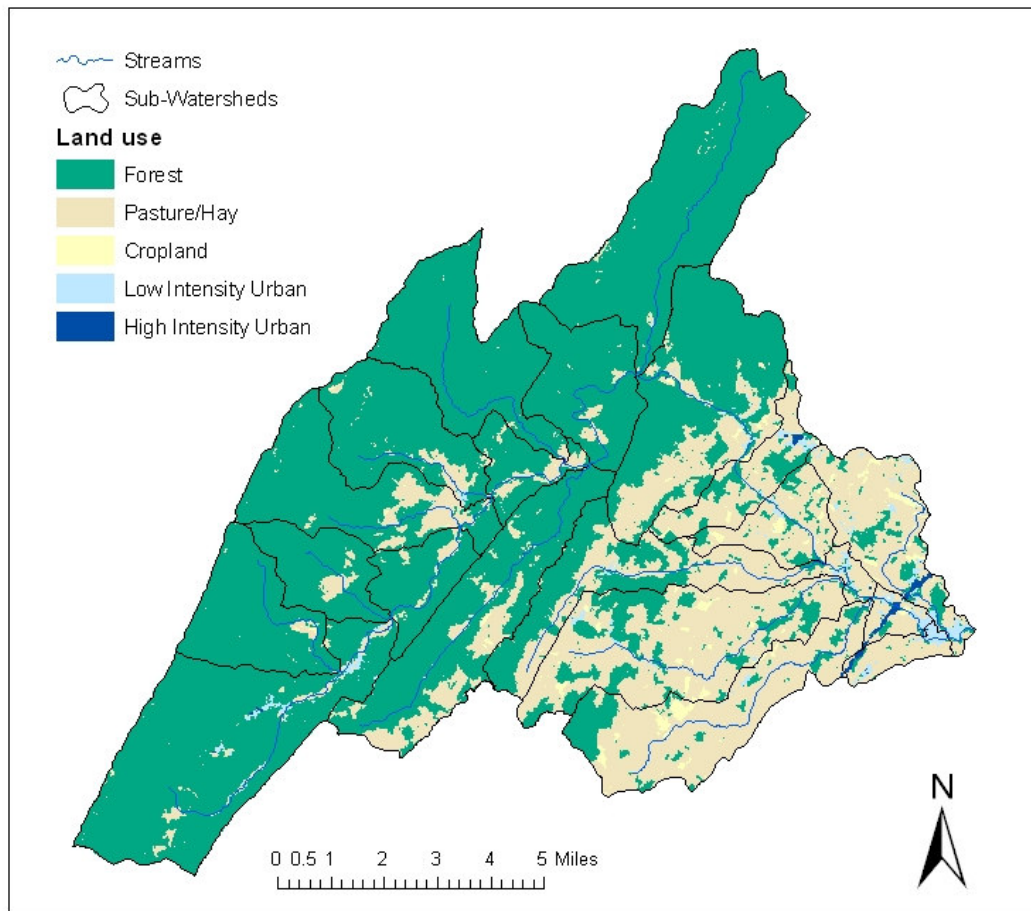


Figure 3.7. Stony Creek Watershed Land Use Distribution.

3.6. Stream Flow Data

Flow is monitored in North Fork Shenandoah at two locations: USGS 01632000 is located upstream of the impaired segment, draining an area of 210 mi² with a mean flow of 190.84 cfs; USGS 01634000 is located at the lower end of the watershed, draining an area of 768 mi² with a mean flow of 582.38 cfs (Figure 3.2). Both stations began monitoring daily stream flow in April 1925. The upper North Fork Shenandoah watershed hydrologic calibration was performed using data from USGS 01632000. The calibrated data from the upper watershed was treated as a point inflow while performing the hydrologic calibration for the

lower North Fork Shenandoah River. The lower watershed hydrologic calibration was performed using data from USGS 01634000.

3.7. Water Quality Data

3.7.1. Historic Data – Fecal Coliform

North Fork Shenandoah River

The Virginia Department of Environmental Quality has assessed the North Fork Shenandoah River watershed as having a potential for nonpoint source pollution from agricultural and wildlife runoff (VADEQ, 2004). Of the 125 water quality samples collected by VADEQ from August 1988 to June 2001 at Station ID No. 1BNFS054.75 (Figure 3.8), 5% exceeded the previous single sample maximum fecal coliform standard of 1,000 cfu/100 mL. During the 2004 assessment period, 2 of 9 samples (22%) did not meet the interim fecal coliform standard at station 1BNFS090.16; 10 of 50 samples (20%) did not meet the interim fecal coliform standard at station 1BNFS081.42; and 9 of 53 samples (17%) did not meet the interim fecal coliform standard at station 1BNFS070.67. Consequently, North Fork Shenandoah River was assessed as not supporting the Clean Water Act's Swimming Use Support Goal for the 2004 305(b) report and was included in the 2004 303(d) list (VADEQ, 2004). The single sample maximum fecal coliform standard changed from 1,000 cfu/100 mL to 400 cfu/100 mL in consort with the change from the Fecal Coliform based standard to the *E. coli* based standard (DEQ, 2003).

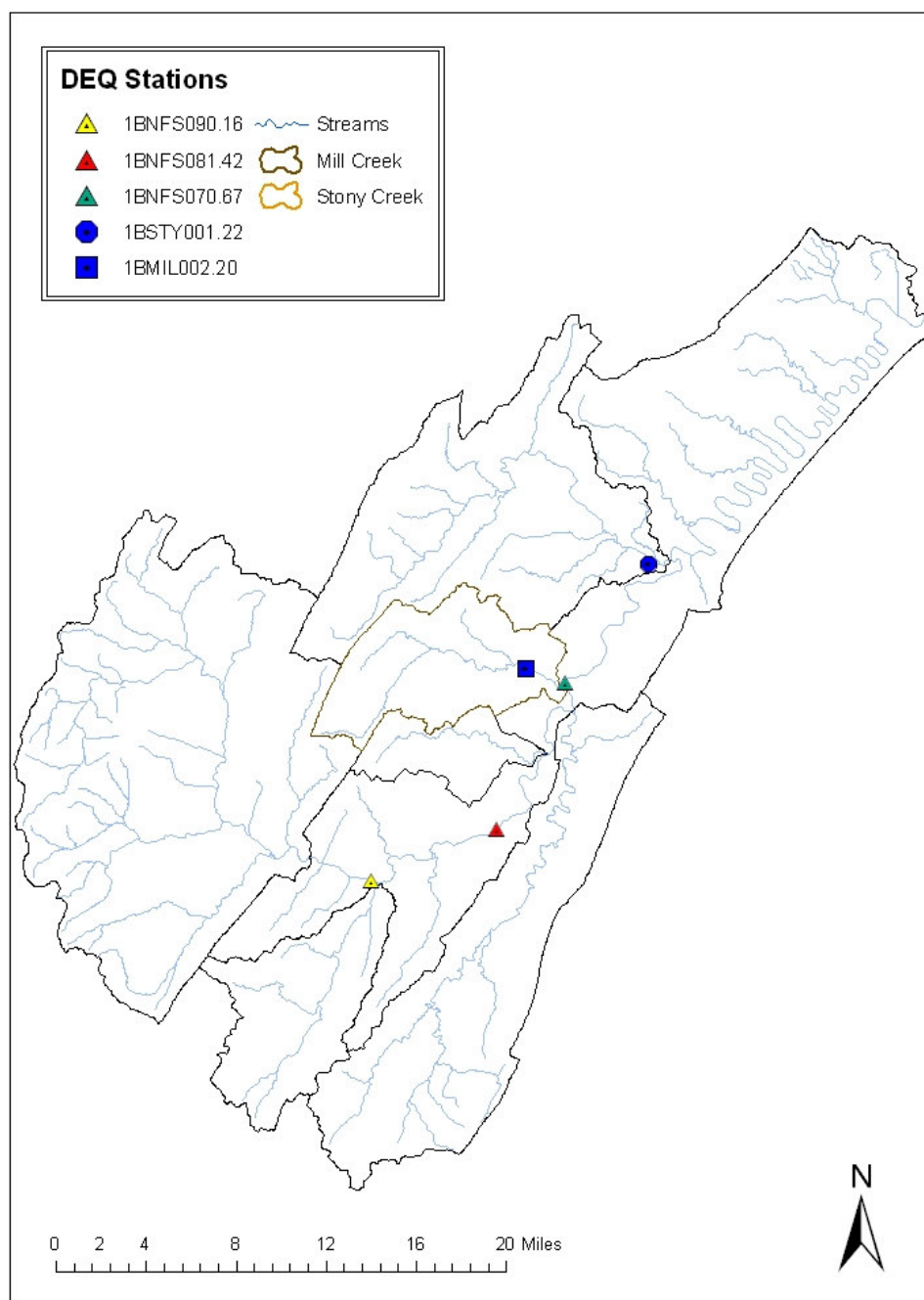


Figure 3.8. Location of Sampling Stations in the Mill Creek, Stony Creek, and North Fork Shenandoah River Watersheds.

The Membrane Filter Method (MFM) was used for the analysis of fecal coliform in water samples for the North Fork Shenandoah River. The samples analyzed with this method had caps of either 100 cfu/100 mL (lower) or 8,000 cfu/100mL (upper). There were no samples recorded that reached the upper limit (Figure 3.9). Violations of the bacteria water quality standard were observed throughout the reporting period.

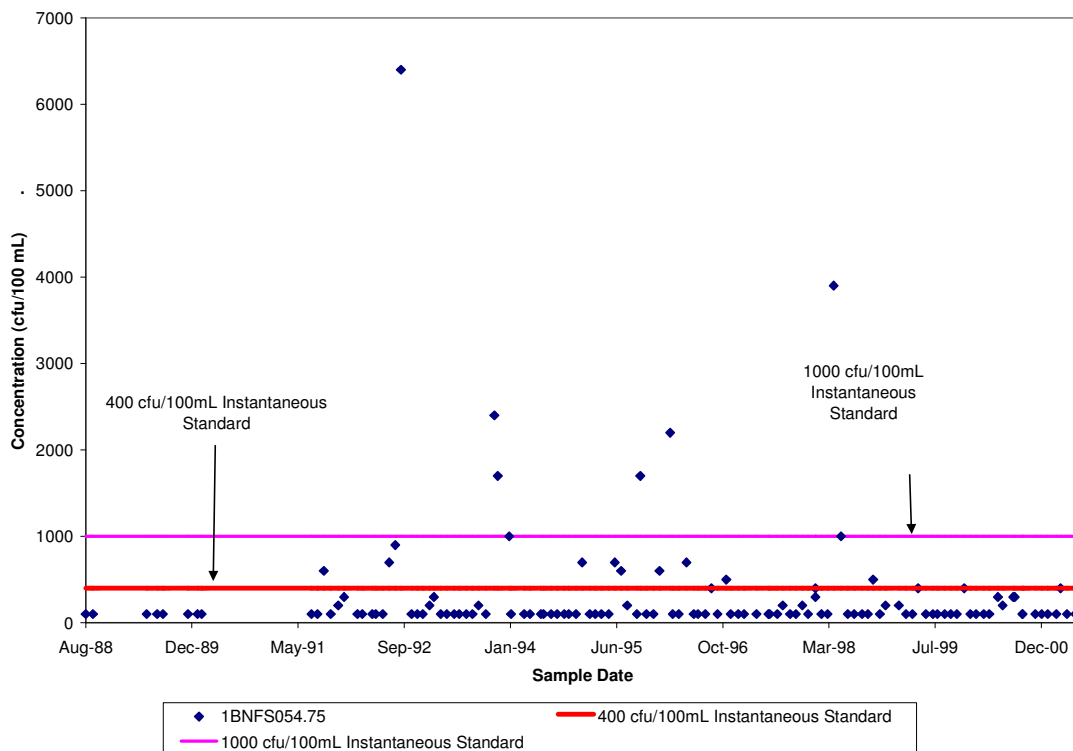


Figure 3.9. Time Series of Fecal Coliform Concentration in North Fork Shenandoah River.

Five samples of *E. coli* were available for the North Fork Shenandoah River. Time series data of *E. coli* concentration over the August 2004 through March 2005 period are shown in Figure 3.10.

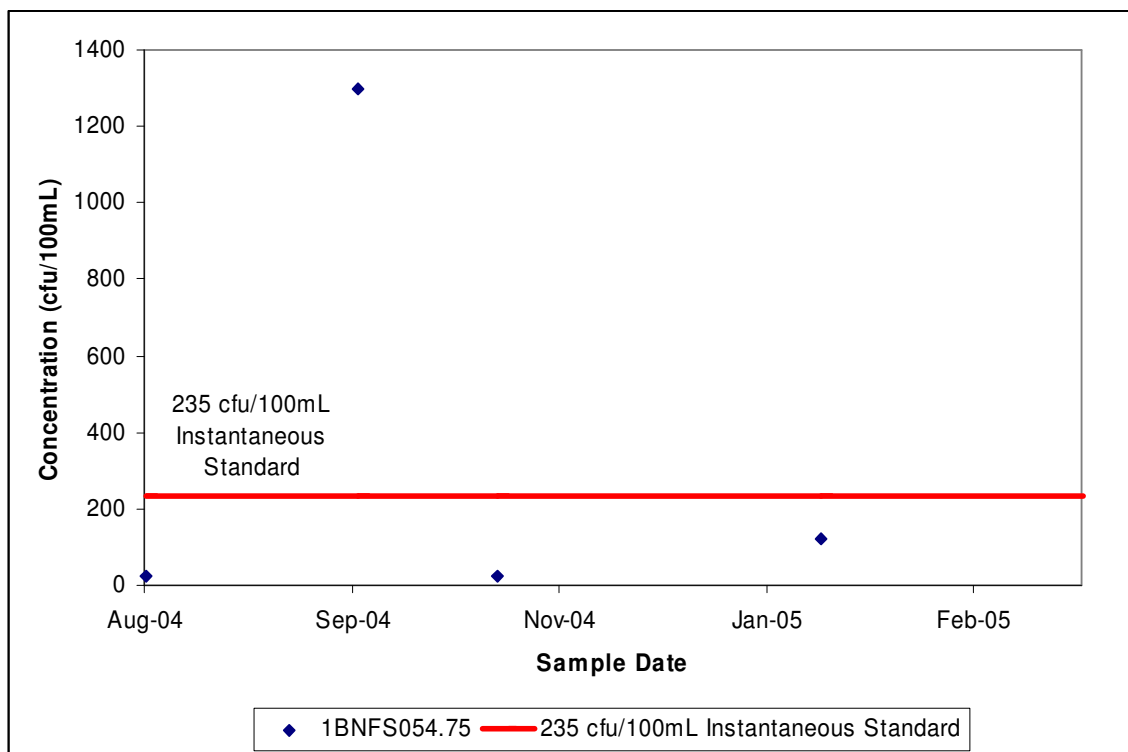


Figure 3.10. Time Series of *E. coli* Concentration in North Fork Shenandoah River.

Seasonality of fecal coliform concentration in the streams was evaluated by plotting the mean monthly fecal coliform concentration values (Figure 3.11). Mean monthly fecal coliform concentration was determined as the average of 8 to 12 values for each month; the number of values varied according to the available number of samples for each month in the 1988 to 2001 period of record.

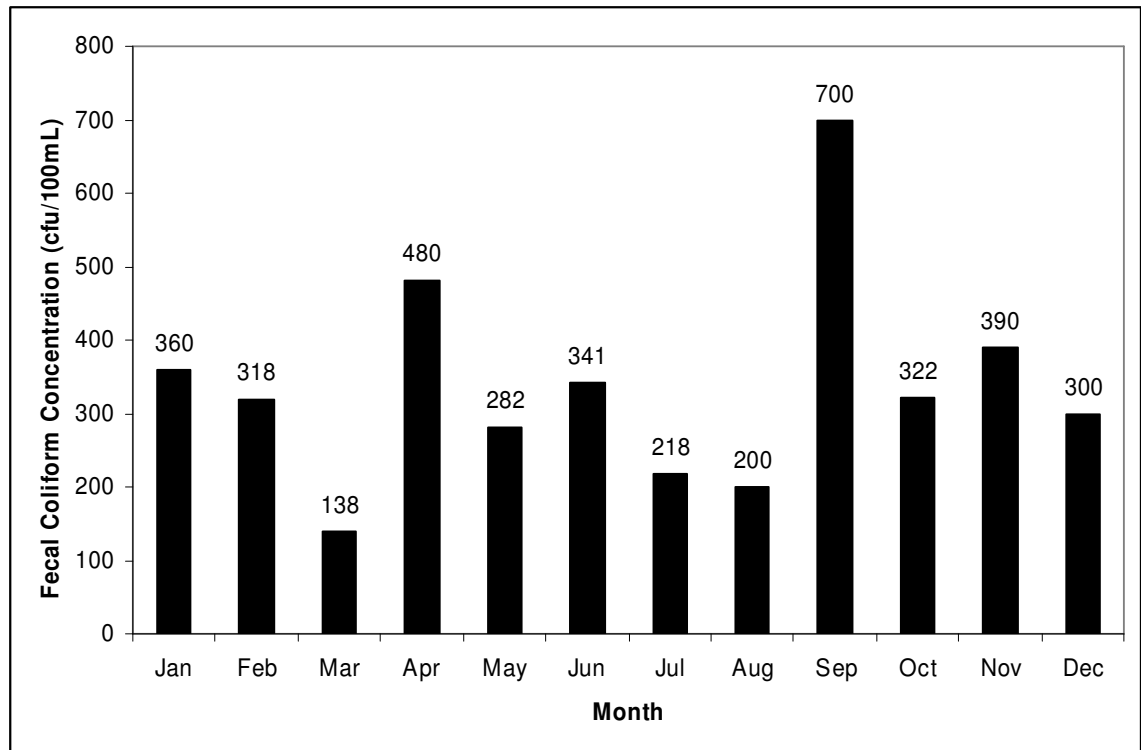


Figure 3.11. Impact of Seasonality on Fecal Coliform Concentrations for the North Fork Shenandoah River.

No strong seasonal trends are apparent for the North Fork Shenandoah River data at station 1BNFS054.75.

Mill Creek

The Virginia Department of Environmental Quality has assessed the Mill Creek watershed as having a potential for nonpoint source pollution from agricultural and wildlife runoff (VADEQ, 2004). Of the 55 water quality samples collected by VADEQ from December 1991 to May 2003 at Station ID No. 1BMIL002.20 (Figure 3.8), 15% exceeded the previous single sample maximum fecal coliform standard of 1,000 cfu/100 mL and 35% exceeded the current single sample maximum fecal coliform standard of 400 cfu/100 mL. Eleven fecal coliform violations were documented at this station out of 30 samples during the 2004 assessment period (VADEQ, 2004). Consequently, Mill Creek was assessed as not supporting the Clean Water Act's Swimming Use Support Goal

for the 2004 305(b) report and was included in the 2004 303(d) list (VADEQ, 2004).

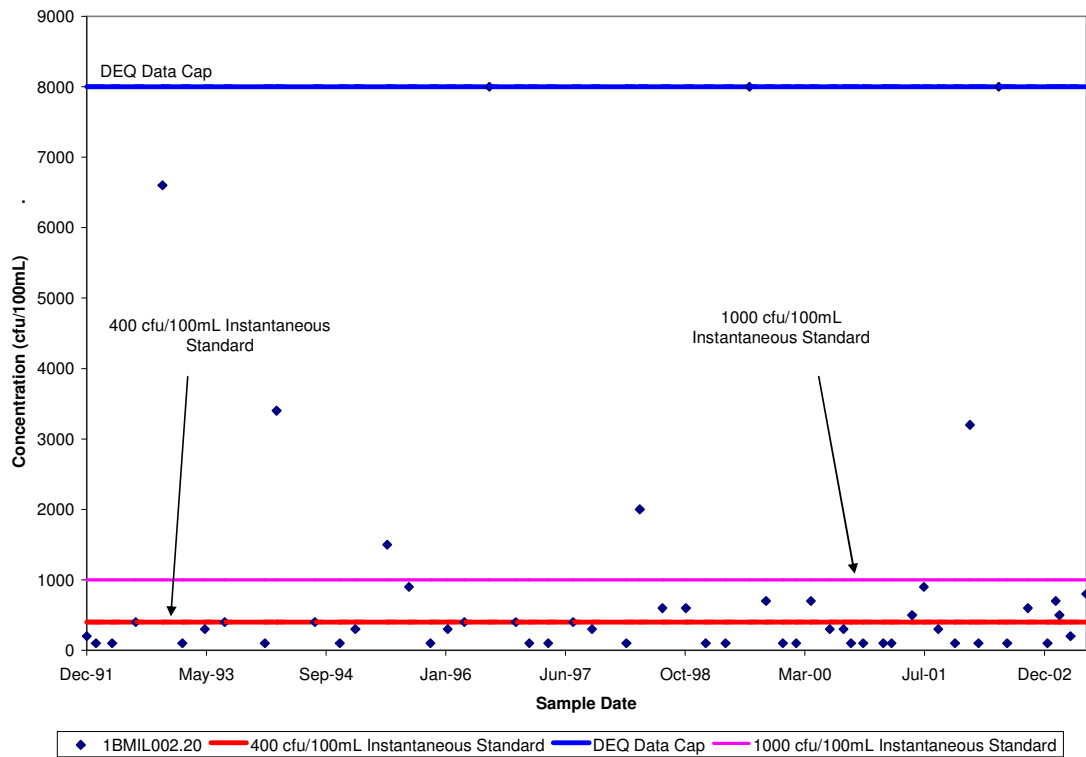


Figure 3.12. Time Series of Fecal Coliform Concentration in Mill Creek.

The Membrane Filter Method (MFM) was used for the analysis of fecal coliform in water samples for Mill Creek. The samples analyzed with this method had caps of either 100 cfu/100 mL (lower) or 8,000 cfu/100mL (upper) (Figure 3.12).

Seasonality of fecal coliform concentration in the streams was evaluated by plotting the mean monthly fecal coliform concentration values (Figure 3.13). Mean monthly fecal coliform concentration was determined as the average of one to nine values for each month; the number of values varied according to the available number of samples for each month in the 1991 to 2003 period of record.

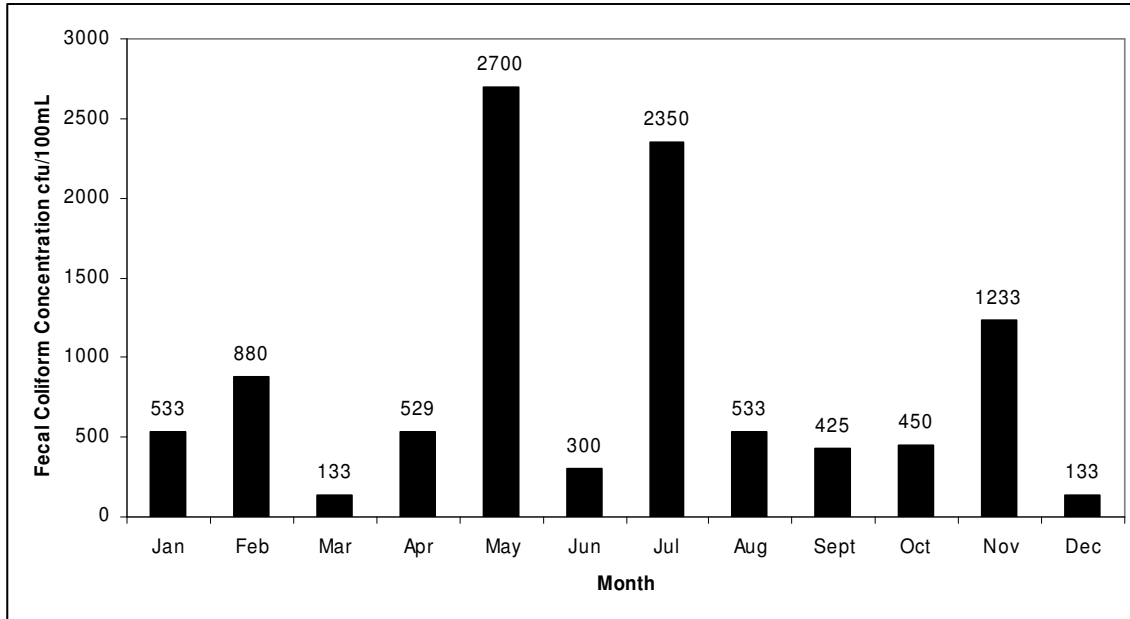


Figure 3.13. Impact of Seasonality on Fecal Coliform Concentrations in Mill Creek.

The summer months appear to have higher bacteria concentrations (note that June was sampled only once during the period of record). This is likely associated with lower stream flows coupled with animals spending more time in streams to avoid heat and insects. Only three samples reached the cap imposed on the fecal coliform count (8000 cfu/100mL); one in May (2002), and two in July (1996 and 1999). No strong trends are evident in the non-summer seasons.

Stony Creek

The Virginia Department of Environmental Quality has assessed the Stony Creek watershed as having a potential for nonpoint source pollution from agricultural and wildlife runoff (VADEQ, 2004). There are two separate segments of Stony Creek that are listed as impaired. Station ID 1BSTY001.22 is located downstream of both segments and was used in calibration. Of the 286 water quality samples collected by VADEQ from April 1973 to June 2004 at Station ID No. 1BSTY001.22 (Figure 3.8), 9% exceeded the previous single sample maximum fecal coliform standard of 1,000 cfu/100 mL and 21% exceeded the current single sample maximum fecal coliform standard of 400 cfu/100 mL. In addition, two fecal coliform violations were documented at this station out of nine

samples during the 2004 assessment period (VADEQ, 2004). Consequently, Stony Creek was assessed as not supporting the Clean Water Act's Swimming Use Support Goal for the 2004 305(b) report and was included in the 2004 303(d) list (VADEQ, 2004).

The Most Probable Number Method (MPN) was used for the majority of the analysis of fecal coliform in water samples for Stony Creek. The samples analyzed with this method had caps of either 100 cfu/100 mL (lower) or 8,000 cfu/100mL (upper) (Figure 3.14). Violations of the bacteria water quality standard were observed throughout the reporting period.

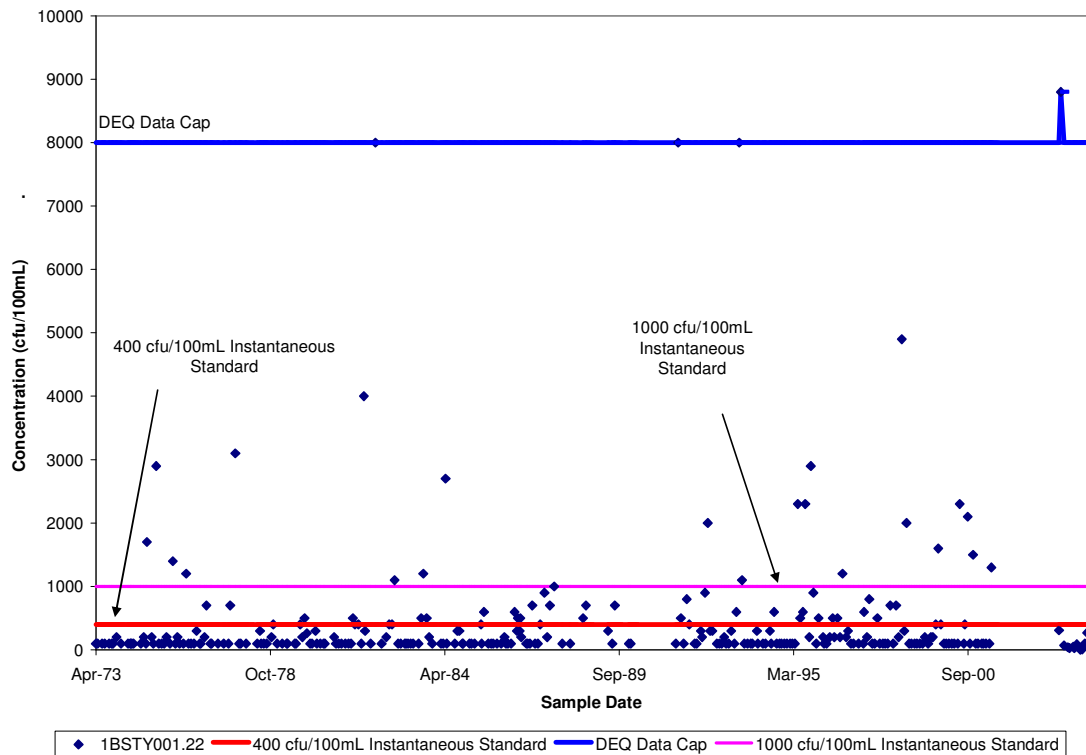


Figure 3.14. Time Series of Fecal Coliform Concentration in Stony Creek

Twenty-two samples of *E. coli* were available for Stony Creek. Time series data of *E. coli* concentration over the July 2003 through January 2005 period are shown in Figure 3.15.

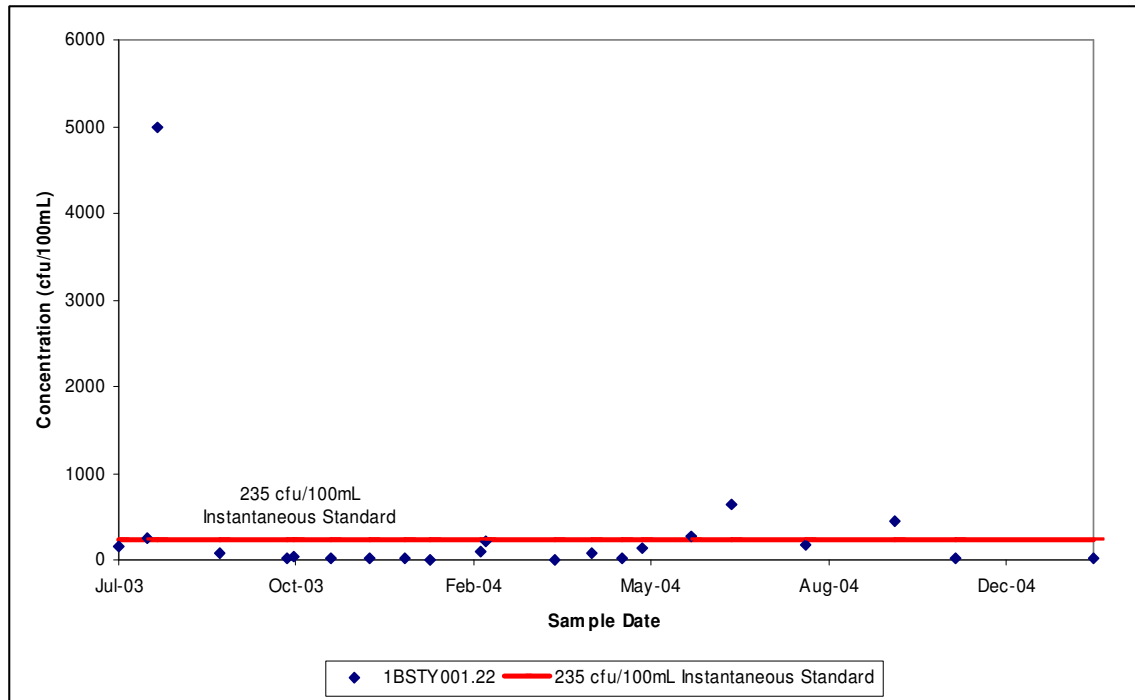


Figure 3.15. Time series of *E. coli* concentration in Stony Creek.

Seasonality of fecal coliform concentration in the streams was evaluated by plotting the mean monthly fecal coliform concentration values (Figure 3.16). Mean monthly fecal coliform concentration was determined as the average of 20 to 28 values for each month; the number of values varied according to the available number of samples for each month in the 1973 to 2004 period of record.

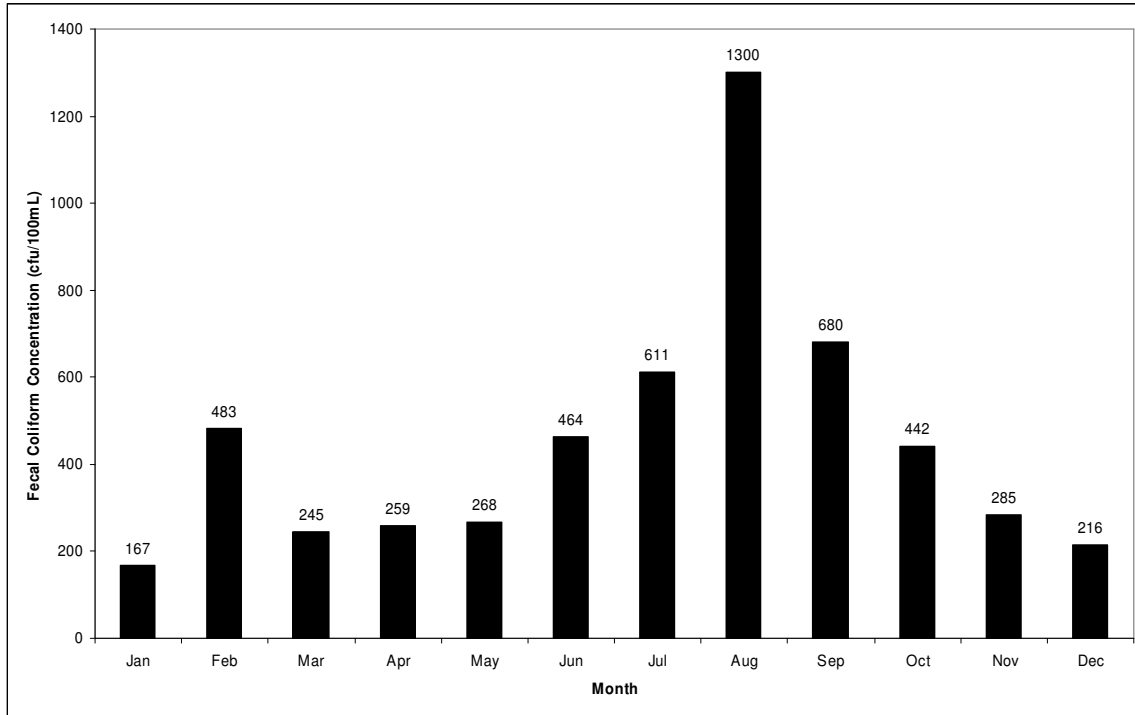


Figure 3.16. Impact of Seasonality on Fecal Coliform Concentrations for Stony Creek.

The data indicate seasonal variability with higher in-stream fecal coliform concentrations occurring during the mid summer and early fall months and lower concentrations typically occurring during the winter months. During mid summer and early fall (July - September), the average fecal coliform concentration was 864 cfu/100mL compared with 289 cfu/100mL during winter (December – February). Again, it should be noted that due to the cap imposed on the fecal coliform count (8,000), where fecal coliform levels are equal to the maximum level, the actual counts could be much higher, increasing the average shown in Figure 3.16.

Chapter 4: SOURCE ASSESSMENT OF FECAL COLIFORM

Fecal coliform sources in the Mill Creek, Stony Creek, and the North Fork of the Shenandoah River watersheds were assessed using information from the following sources: VADEQ, VADCR, Virginia Department of Game and Inland Fisheries (VADGIF), Virginia Department of Agricultural and Consumer Services (VDACS), Virginia Cooperative Extension (VCE), NRCS, public participation, watershed reconnaissance and monitoring, published information, and professional judgment. The upper portion of the North Fork of the Shenandoah River is not described in this section because it was not listed as impaired. Only the lower watershed (the impaired segment) is described. Point sources and potential nonpoint sources of fecal coliform are described in detail in the following sections and summarized in Table 4.2 for Mill Creek, Table 4.16 for Stony Creek, and Table 4.29 for the North Fork of the Shenandoah River.

Point sources of fecal coliform bacteria in the three watersheds include all municipal and industrial plants that treat human waste, as well as private residences that fall under general permits. Virginia issues Virginia Pollutant Discharge Elimination System (VPDES) permits for point sources of pollution. In Virginia, point sources that treat human waste are required to maintain a fecal coliform concentration of 200 cfu/100 mL or less in their effluent. There were 106 permits in the impaired watersheds (Table 4.1). In allocation scenarios for bacteria, the entire allowable point source discharge concentration of 200 cfu/100 mL was used.

Table 4.1. VPDES and General Permits discharging into Mill Creek, Stony Creek, and the North Fork of the Shenandoah River.

Permit Number	Facility Name	Design Flow (MGD)	Permitted E. <i>Coli</i> Conc. (cfu/100 mL)	E. <i>Coli</i> Load (cfu/year)
VA0020508	Edinburg STP	0.175	126	3.05×10^{11}
VA0021342	New Market Battlefield State Historical Park STP	0.01	126	1.74×10^{10}
VA0022853	New Market STP	0.5	126	8.70×10^{11}
VA0026441	Mt Jackson STP	0.6	126	1.04×10^{12}
VA0026468	Woodstock STP	2	126	3.48×10^{12}
VA0028380	Stoney Creek Sanitary District STP	0.6	126	1.04×10^{12}
VA0028401	Shrine Mont STP	0.039	126	6.79×10^{10}
VA0077402	Georges Chicken LLC	1.7	126	2.96×10^{12}
VA0088846	Johns Manville	0.007	126	1.22×10^{10}
VA0090263	North Fork Modular Reclamation & Reuse Facility	1.923	126	3.35×10^{12}
VA0090328	North Fork Regional WWTP	0.75	126	1.31×10^{12}
	95 Single Family Home Permits	0.001	126	1.65×10^{11}

4.1. Mill Creek Sources

A synopsis of the fecal coliform sources characterized and accounted for in the Mill Creek watershed, along with average fecal coliform production rates, are shown in Table 4.2.

Table 4.2. Potential fecal coliform sources and daily fecal coliform production by source in Mill Creek watershed.

Potential Source	Population in Watershed	Fecal coliform produced ($\times 10^6$ cfu/head-day)
Humans	2,131	1,950 ^a
Dairy cattle		
Milk and dry cows	253	20,200 ^b
Heifers ^c	110	9,200 ^d
Beef cattle	1,988	20,000
Pets	870	450 ^e
Poultry		
Chicken Broilers	1,256,100	136 ^f
Turkey Toms	116,000	93 ^f
Sheep		
Ewes	231	12,000 ^f
Lambs	462	
Horses	119	420 ^f
Deer	1,399	350
Raccoons	619	50
Muskrats	112	25 ^g
Beavers	11	0.2
Wild Turkeys	292	93 ^f
Ducks	376	800
Geese	451	2,400

^a Source: Geldreich *et al.* (1978)

^b Based on data presented by Metcalf and Eddy (1979) and ASAE (1998)

^c Includes calves

^d Based on weight ratio of heifer to milk cow weights and fecal coliform produced by milk cow

^e Source: Weiskel *et al.* (1996)

^f Source: ASAE (1998)

^g Source: Yagow (2001)

4.1.1. Humans and Pets

The Mill Creek watershed has an estimated population of 2,131 people (867 households at an average of 2.46 people per household; actual people per household varies by sub-watershed). Fecal coliform from humans can be

transported to streams from failing septic systems or via straight pipes discharging directly into streams.

4.1.1.a. Failing Septic Systems

Septic system failure can be evidenced by the rise of effluent to the soil surface. Surface runoff can transport the effluent containing fecal coliform to receiving waters. There were no sewered areas in the Mill Creek watershed. Unsewered housing age was determined from the 2000 Census of Population and Housing Tables. The census data were analyzed at the block group level and an area weighting method was used to calculate the number of homes in a sub-watershed. Tab number H34 in Summary File 3 of the 2000 Census classifies homes into nine classes based on the age of the structure. For watershed characterization and modeling purposes houses were defined in three categories: *old homes*, built before 1969; *middle-aged homes*, built between 1970 and 1989; and *new homes*, built after 1990. Each age category was calculated as a percent of the total number of homes in a given sub-watershed. Professional judgment was applied in assuming that septic system failure rates for houses in the *old homes*, *middle-aged homes*, and *new homes* categories were 40, 20, and 3%, respectively (R.B. Reneau, personal communication, 3 December 1999, Blacksburg, Va.). Estimates of these failure rates were also supported by the Holmans Creek Watershed Study (a tributary to the North Fork of the Shenandoah River), which found that over 30% of all septic systems checked in the watershed were either failing or not functioning at all (SAIC, 2001).

Daily total fecal coliform load to the land from a failing septic system in a particular sub-watershed was determined by multiplying the average occupancy rate for that sub-watershed (occupancy rate ranged from 1.11 to 4.66 persons per household (Census Bureau, 2000)) by the per capita fecal coliform production rate of 1.95×10^9 cfu/day (Geldreich et al., 1978). Hence, the total fecal coliform loading to the land from a single failing septic system in a sub-watershed with an occupancy rate of 1.11 persons/household was 2.15×10^9

cfu/day. Transport of some portion of the fecal coliform to a stream by runoff may occur. The number of failing septic systems in the watershed is given in Table 4.3.

4.1.1.b. Straight Pipes

Of the houses located within 150 ft of streams, in the *old homes*, *middle-aged homes*, and *new homes* categories, 10%, 2%, and 0% respectively, were estimated to have straight pipes (R.B. Reneau, personal communication, 3 December 1999, Blacksburg, Va.).

4.1.1.c. Pets

Assuming one pet per household, there are 865 pets in Mill Creek watershed. A dog produces fecal coliform at a rate of 0.45×10^9 cfu/day (Weiskel et al., 1996); this was assumed to be representative of a 'unit pet' – one dog or several cats. The pet population distribution among the sub-watersheds is listed in Table 4.3. Pet waste is generated in the rural residential and urban residential land use types. Surface runoff can transport bacteria in pet waste from residential areas to the stream.

Table 4.3. Estimated number of unsewered houses by age category, number of failing septic systems, and pet population in Mill Creek watershed.

Sub-watershed	Unsewered houses in each age category (no.)			Failing septic systems (no.)	Pet population ^a
	Old	Mid-Age	New		
MC-56	51	31	14	6	96
MC-57	69	37	15	8	121
MC-58	25	14	5	2	44
MC-59	56	50	18	7	123
MC-60	64	67	28	7	158
MC-61	36	38	16	5	89
MC-62	21	54	17	3	92
MC-63	32	38	15	4	85
MC-64	25	24	10	3	59
Total	379	352	136	45	867

^a Assumed an average of one pet per household.

4.1.2. Cattle

Fecal coliform in cattle waste can be directly excreted to the stream, or it can be transported to the stream by surface runoff from animal waste deposited on pastures or applied to crop, pasture, and hay land.

4.1.2.a. Distribution of Dairy and Beef Cattle in the Mill Creek Watershed

There are 2 dairy farms in the watershed, based on reconnaissance and information from VDACS. From communication with local dairy farmers, it was determined that there are 224 milk cows, 29 dry cows, and 110 heifers in the watershed (Table 4.2). The dairy cattle population was distributed among the sub-watersheds based on the location of the dairy farms. Table 4.4 shows the number of dairy operations for each sub-watershed.

Table 4.4. Distribution of dairy cattle, dairy operations and beef cattle among Mill Creek sub-watersheds.

Sub-watershed	Dairy cattle	No. of dairy operations	Beef cattle
MC-56	0	0	150
MC-57	233	1	346
MC-58	0	0	89
MC-59	0	0	351
MC-60	130	1	637
MC-61	0	0	248
MC-62	0	0	58
MC-63	0	0	98
MC-64	0	0	11
Total	363	2	1,986

Beef cattle in the watershed included cow/calf and feeder operations. The exact number of beef operations in the watershed is not known; the beef cattle population (1,988 cattle) in the watershed was estimated based on communications with Dr. Dan Eversole, the beef specialist at Virginia Tech (August 14, 2002), regarding stocking rates for various pasture categories. The stocking rates were particular to the classification of pasture areas. Because no distinction is made in the NLCD as to quality of pasture, the stocking rate for unimproved pastures (the middle level of pasture) was used in this study. The

carrying capacity for unimproved pasture was determined based on communication with Dr. Dan Eversole; stocking rates for unimproved pasture were determined as a combination of information on the carrying capacity of the pastures and data from VADCR. The beef cattle stocking rate for unimproved pasture determined in this fashion was 0.36 beef cattle/acre. The number of beef cattle in each sub-watershed (Table 4.4) was calculated by multiplying the pasture acreage in that sub-watershed by the stocking rate.

Beef and dairy cattle spend varying amounts of time in confinement, loafing lots, streams, and pasture depending on the time of year and type of cattle (e.g., milk cow versus heifer). Accordingly, the proportion of fecal coliform deposited in any given land area varies throughout the year. Based on discussions with NRCS, VADCR, VCE, and local producers, the following assumptions and procedures were used to estimate the distribution of cattle (and thus their manure) among different land use types and in the stream.

- a) Cows are confined according to the schedule given in Table 4.5.
- b) When the milk cows are not confined or in loafing lots, they spend 100% of the time on pasture. All other dairy (dry cows and heifers) and beef cattle are also on pastures when not in confinement or loafing lots.
- c) Beef cows on pastures that are contiguous to streams (1,091 acres for all sub-watersheds, Table 4.6) have stream access. According to information from the contacted dairy farmers, no dairy cows have stream access in the Mill Creek watershed.
- d) Cows with stream access spend varying amounts of time in the stream during different seasons (Table 4.5). Cows spend more time in the stream during the three summer months to protect their hooves from hornflies, among other reasons.
- e) Thirty percent of cows in and around streams directly deposit fecal coliform into the stream. The remaining 70% of the manure is deposited on pastures.

Table 4.5. Time spent by cattle in confinement and in the stream.

Month	Time spent in confinement (%)		Time spent in the stream (hours/day) ^a
	Milk cows	Dry cows, heifers, and beef cattle	
January	75%	40%	0.50
February	75%	40%	0.50
March	40%	0%	0.75
April	30%	0%	1.00
May	30%	0%	1.50
June	30%	0%	3.50
July	30%	0%	3.50
August	30%	0%	3.50
September	30%	0%	1.50
October	30%	0%	1.00
November	40%	0%	0.75
December	75%	40%	0.50

^a Time spent in and around the stream by cows that have stream access.

Table 4.6. Pasture acreages contiguous to stream.

Sub-watershed	Pasture Area (ac)	% ^a	Pasture Area Contiguous to Streams (ac)
MC-01	979	4%	39
MC-02	2258	4%	90
MC-03	582	9%	52
MC-04	2291	13%	298
MC-05	4159	4%	166
MC-06	1618	9%	146
MC-07	379	20%	76
MC-08	638	27%	172
MC-09	72	71%	51
Total	12,976	8%	1,091

^a Percent of area contiguous to stream to the total pasture area of that type in that sub-watershed.

A sample calculation for determining the distribution of cattle to different land use types and to the stream is shown in Appendix B. The resulting numbers of cattle in each land use type as well as in the stream for all sub-watersheds are given in Table 4.7 for dairy cattle and in Table 4.8 for beef cattle.

Table 4.7. Distribution of the dairy cattle^a population.

Month	Confined	Pasture	Streams^b
January	203	160	0
February	203	160	0
March	148	215	0
April	148	215	0
May	148	215	0
June	148	215	0
July	148	215	0
August	148	215	0
September	148	215	0
October	148	215	0
November	148	215	0
December	203	160	0

^a Includes milk cows, dry cows, and heifers.

^b Number of dairy cattle defecating in stream.

Table 4.8. Distribution of the beef cattle population.

Months	Confined	Pasture	Stream^a
January	914	1,371	1
February	1,074	1,609	1
March	0	2,761	2
April	0	2,840	3
May	0	2,918	5
June	0	2,991	11
July	0	3,070	11
August	0	3,149	12
September	0	3,235	5
October	0	1,986	2
November	0	2,086	2
December	875	1,311	1

^a Number of beef cattle defecating in stream.

4.1.2.b. Direct Manure Deposition in Streams

Direct manure loading to streams is due to beef cattle (Table 4.8) defecating in the stream. However, only cattle on pastures contiguous to streams have stream access. Manure loading increases during the warmer months when cattle spend more time in water, compared to the cooler months. Average annual manure loading directly deposited by cattle in the stream for the watershed is 100,685 lb. Daily fecal coliform loading due to cows depositing in the stream, averaged over the year, is 1.22×10^{11} cfu/day. Part of the fecal coliform deposited in the stream stays suspended while the remainder adsorbs to the sediment in the streambed. Under base flow conditions, it is likely that suspended fecal coliform bacteria are the primary form transported with the flow. Sediment-bound fecal coliform bacteria are likely to be re-suspended and transported to the watershed outlet under high flow conditions. Die-off of fecal coliform in the stream depends on sunlight, predation, turbidity, and other environmental factors.

4.1.2.c. Direct Manure Deposition on Pastures

Dairy (Table 4.7) and beef (Table 4.8) cattle that graze on pastures but do not deposit in streams contribute the majority of fecal coliform loading on pastures. Manure loading on pasture was estimated by multiplying the total number of each type of cattle (milk cow, dry cow, heifer, and beef) on pasture by the amount of manure produced per day. The total amount of manure produced by all types of cattle was divided by the pasture acreage to obtain manure loading (lb/ac-day) on pasture. Fecal coliform loading (cfu/ac-day) on pasture was calculated by multiplying the manure loading (lb/ac-day) by the fecal coliform content (cfu/lb) of the manure. Because the confinement schedule of the cattle changes with season, manure and fecal coliform loading on pasture also change with season.

Average annual cattle manure loadings to pasture were 4,576 lb/ac-year. Fecal coliform loadings to pasture from cattle on a daily basis, averaged over the year, are 5.75×10^9 cfu/ac-day. Fecal coliform bacteria deposited on the pasture

surface are subject to die-off due to desiccation and ultraviolet (UV) radiation. Runoff can transport part of the remaining fecal coliform to receiving waters.

4.1.2.d. Land Application of Liquid Dairy Manure

A typical milk cow weighs 1,400 lb and produces 17 gallons of liquid manure daily (ASAE, 1998). Based on the monthly confinement schedule (Table 4.7) and the number of milk cows (Table 4.2), annual liquid dairy manure production in the watershed is 7.0 million gallons. Based on per capita fecal coliform production of milk cows, the fecal coliform concentration in fresh liquid dairy manure is 1.18×10^9 cfu/gal. Liquid dairy manure receives priority over other manure types (poultry litter and solid cattle manure) when applied to land. Liquid dairy manure application rates are 6,600 and 3,900 gal/ac-year to cropland and pasture land use categories, respectively, with cropland receiving priority in application. Based on availability of land and liquid dairy manure, as well as the assumptions regarding application rates and priority of application, it was estimated that liquid dairy manure was applied to 139 acres (21%) of cropland. Because there was more than enough crop area to receive the liquid manure produced in the watershed, no liquid dairy manure was applied to pasture.

The typical crop rotation in the watershed is a seven-year rotation with three years of corn-rye and four years of rotational hay. It was assumed that 50% of the corn acreage was under no-till cultivation. Liquid manure is applied to cropland during February through May (prior to planting) and in October-November (after the crops are harvested). For spring application to cropland, liquid manure is applied on the soil surface to rotational hay and no-till corn, and is incorporated into the soil for corn in conventional tillage. In fall, liquid manure is incorporated into the soil for cropland under rye, and surface-applied to cropland under rotational hay. In all months except December and January, liquid manure can be surface-applied to pasture. It was assumed that only 10% of the subsurface-applied fecal coliform was available for removal in surface runoff based on local knowledge. The application schedule of liquid manure is

given in Table 4.9. Dry cows and heifers were assumed to produce only solid manure.

Table 4.9. Schedule of cattle and poultry waste application in the Mill Creek watershed.

Month	Liquid manure applied (%) ^a		Solid manure or poultry litter applied (%) ^a	
	Crops	Pasture	Crops	Pasture
January	0	0	0	0
February	7.1	5	6.7	5
March	35.7	25	33.3	25
April	28.6	20	26.7	20
May	7.1	5	6.7	5
June	0	10	0	5
July	0	0	0	5
August	0	5	0	5
September	0	15	0	10
October	7.1	5	13.3	10
November	14.3	10	13.3	10
December	0	0	0	0

^a As percent of annual load applied to each land use type.

4.1.2.e. Land Application of Solid Manure

Solid manure produced by dry cows, heifers, and beef cattle during confinement is collected for land application. It was assumed that milk cows produce only liquid manure while in confinement. The number of cattle, their typical weights, amounts of solid manure produced, and fecal coliform concentration in fresh manure are given in Table 4.10. Solid Manure is last on the priority list for application to land (it falls behind liquid manure and poultry litter). The amount of solid manure produced in each sub-watershed was estimated based on the populations of dry cows, heifers, and beef cattle in the sub-watershed (Table 4.4) and their confinement schedules (Table 4.5). Solid manure from dry cows, heifers, and beef cattle contained different fecal coliform concentrations (cfu/lb) (Table 4.10).

Table 4.10. Estimated population of dry cows, heifers, and beef cattle, typical weights, per capita solid manure production, and fecal coliform concentration in fresh solid manure in individual cattle type.

Type of cattle	Population	Typical weight (lb)	Solid manure produced (lb/animal-day)	Fecal coliform concentration in fresh manure ($\times 10^6$ cfu/lb)
Dry cow	29	1,400 ^a	115.0 ^b	176 ^c
Heifer	110	640 ^d	40.7 ^a	226 ^c
Beef	1,986	1,000 ^e	60.0 ^b	333 ^c

^a Source: ASAE (1998)

^b Source: MWPS (1993)

^c Based on per capita fecal coliform production per day (Table 4.2) and manure production

^d Based on weighted average weight assuming that 57% of the animals are older than 10 months (900 lb ea.), 28% are 1.5-10 months (400 lb ea.) and the remainder are less than 1.5 months (110 lb ea.) (MWPS, 1993).

^e Based on input from local producers

Solid manure is applied at the rate of 12 tons/ac-year to both cropland and pasture, with priority given to cropland. As in the case of liquid manure, solid manure is only applied to cropland during February through May, October, and November. Solid manure can be applied to pasture during the whole year, except December and January. The method of application of solid manure to cropland or pasture is assumed to be identical to the method of application of liquid dairy manure. The application schedule for solid manure is given in Table 4.9. Based on availability of land and solid manure, as well as the assumptions regarding application rates and priority of application, it was estimated that solid cattle manure was applied to 36 acres (5.4%) of the cropland and 179 acres (1.4%) of pasture.

4.1.3. Poultry

The poultry population (Table 4.2) was estimated based on the permitted combined feeding operations (CAFO) located within the watershed and discussions with local producers and nutrient management specialists. Poultry litter production was estimated from the poultry population after accounting for the time when the houses are not occupied.

Because poultry is raised entirely in confinement, all litter produced is collected and stored prior to land application. The estimated production rate of poultry litter in the Mill Creek watershed is 1.63×10^7 lb/year, which corresponds to a fecal coliform production rate of 1.64×10^{16} cfu/year. This fecal coliform produced is subject to die-off in storage and losses due to incorporation prior to being subject to transport via runoff. Poultry litter is applied at the rate of 3 tons/ac-year first to cropland, and then to pastures at the same rate. Poultry litter receives priority after all liquid manure has been applied (i.e., it is applied before solid cattle manure is considered). The method of poultry litter application to cropland and pastures is assumed to be identical to the method of cattle manure application. The application schedule of poultry litter is given in Table 4.9. As with liquid and solid manures, poultry litter is not applied to cropland during June through September. Based on availability of land and poultry litter, as well as the assumptions regarding application rates and priority of application, it was estimated that poultry litter was applied to 417 acres (62%) of cropland and 4,710 acres (36%) of pasture.

4.1.4. Sheep

The sheep population (Table 4.2) was estimated based on discussions with nutrient management specialists, observations of the watershed, and discussions with stakeholders. The sheep herd was composed of lambs and ewes. The lamb population was expressed in equivalent sheep numbers. The equivalent sheep population calculated for lambs was based on the assumption that the average weight of a lamb is half of the weight of a sheep. The lamb population for the Mill Creek watershed was estimated to be 462 animals. The equivalent sheep population for the lambs was 231. The total number of sheep for the Mill Creek watershed was the sum of the number of ewes (231) and the equivalent number of lambs (231) for a total of 462 animals. The sheep were kept on pasture. The relative stocking density for sheep was estimated to be 0.6/acre of pasture. The equivalent sheep population for each sub-watershed is shown Table 4.11. Sheep are not usually confined and tend not to wade or

defecate in the streams. Therefore, the fecal coliform produced by sheep was added to the loads applied to pasture.

Table 4.11. Sheep Populations in Mill Creek Sub-Watersheds.

Sub-watershed	Ewe Population	Lamb Population
MC-56	18	36
MC-57	40	80
MC-58	10	20
MC-59	41	82
MC-60	74	148
MC-61	29	58
MC-62	7	14
MC-63	11	22
MC-64	1	2
Total	231	462

Pasture has average annual sheep manure loadings of 32 lb/ac-year. Fecal coliform loadings for pasture from sheep on a daily basis averaged over the year are 2.18×10^{10} cfu/ac-day.

4.1.5. Horses

Horse populations for the Mill Creek watershed were obtained through observations of the watershed and communication with local producers. The total horse population was estimated to be 119. The distribution of horse population among the sub-watersheds is listed in Table 4.12. Horses are not usually confined and tend not to wade or defecate in the streams. Therefore, the fecal coliform produced by horses was added to the loads applied to pasture. Fecal coliform loadings from horses on a daily basis averaged over the year and over pasture areas in the entire watershed are 1.97×10^8 cfu/ac-day.

Table 4.12. Horse Populations among Mill Creek Sub-Watersheds.

Sub-watershed	Horse Population
MC-56	9
MC-57	21
MC-58	5
MC-59	21
MC-60	38
MC-61	15
MC-62	3
MC-63	6
MC-64	1
Total	119

4.1.6. Wildlife

Wildlife fecal coliform contributions can be from excretion of waste on land and from excretion directly into streams. Information provided by VADGIF, professional trappers, and watershed residents were used to estimate wildlife populations. Wildlife species that were found in quantifiable numbers in the watershed included deer, raccoon, muskrat, beaver, wild turkey, goose, and wood duck. Population numbers for each species and fecal coliform amounts were determined (Table 4.2) along with preferred habitat and habitat area (Table 4.13).

Professional judgment was used in estimating the percent of each wildlife species depositing directly into streams, considering the habitat area each occupied (Table 4.13). Fecal matter produced by deer that is not directly deposited in streams is distributed among pastures and forest. Raccoons deposit their waste in streams and forests. Muskrats deposit their waste in streams, forest, and cropland.

Fecal loading from wildlife was estimated for each sub-watershed. The wildlife populations were distributed among the sub-watersheds based on the area of appropriate habitat in each sub-watershed. For example, the deer population was evenly distributed across the watershed, whereas the length of stream and impoundment shoreline determined the muskrat population. Therefore, a sub-watershed with more stream length and impoundments would

have more muskrats than a sub-watershed with shorter stream length and fewer impoundments, and less area in forest and crop land use. Distribution of wildlife among sub-watersheds is given in Table 4.14.

Table 4.13. Wildlife habitat description and acreage, and percent direct fecal deposition in streams.

Wildlife type	Habitat	Acres of habitat	Population Density (animal/ac-habitat)	Direct fecal deposition in streams (%)
Deer	Entire Watershed	29,766	0.047	0.5%
Raccoon	low density on forests not in high density area; high density on forest within 600 ft of a permanent water source or 0.5 mile of cropland	8,845	Low density: 10 High density: 30	5%
Muskrat	16/mile of ditch or medium sized stream intersecting cropland; 8/mile of ditch or medium sized stream intersecting pasture; 10/mile of pond or lake edge; 50/mile of slow-moving river edge	41	-see habitat column-	12.5%
Beaver	300 ft buffer streams and impoundments in forest and pasture	73	0.015	25%
Geese	300 ft buffer around main streams	1,694	0.078 - off season 0.1092 - peak season	12.5%
Wood Duck	300 ft buffer around main streams	1,709	0.0624 - off season 0.0936 - peak season	12.5%
Wild Turkey	Entire Watershed except residential	29,200	0.01	5%

Table 4.14. Distribution of wildlife among sub-watersheds.

Sub-watershed	Deer	Raccoon	Muskrat	Beaver	Geese	Wood Duck	Wild Turkey
MC-56	66	13	4	0	20	17	12
MC-57	126	17	6	0	21	18	26
MC-58	33	4	5	0	13	10	7
MC-59	199	85	28	0	75	62	42
MC-60	258	54	17	1	51	42	54
MC-61	157	78	14	1	41	35	33
MC-62	218	153	8	4	88	73	46
MC-63	200	134	23	1	67	56	42
MC-64	142	81	7	4	75	63	30
Total	1,399	619	112	11	451	376	292

4.1.7. Summary: Contribution from All Sources

Based on the inventory of sources discussed in this chapter, a summary of the contribution by the different nonpoint sources to direct annual fecal coliform loading to the streams is given in Table 4.15. Distribution of annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Table 4.15.

From Table 4.15, it is clear that nonpoint source loadings to the land surface are 360 times larger than direct loadings to the streams (not including commercial sources), with pastures receiving about 99% of the total fecal coliform load. It is premature to assume that most of the fecal coliform loading in streams originates from upland sources, primarily from pastures. Other factors such as precipitation amount and pattern, size of runoff events, manure application activities (time and method), type of waste (solid versus liquid manure), and proximity to streams also impact the amount of fecal coliform from upland areas that reaches the streams. The HSPF model considers these factors when estimating fecal coliform loads to the receiving waters, as described in Chapter 5.

Table 4.15. Annual fecal coliform loadings to the stream and the various land use categories in the Mill Creek watershed.

Source	Fecal coliform loading (x10¹² cfu/year)	Percent of total loading
Direct loading to streams		
Cattle in stream	44	<1%
Wildlife in stream	24	<1%
Straight pipes	7	<1%
Loading to land surfaces		
Cropland	130	<1%
Pasture	27,219	99%
Residential ^a	20	<1%
Forest	168	<1%
Total	27,537	

^a Includes loads received from both High and Low Density Residential due to failed septic systems and pets.

4.2. Stony Creek Sources

A synopsis of the fecal coliform sources characterized and accounted for in the Stony Creek watershed, along with average fecal coliform production rates are shown in Table 4.16.

Table 4.16. Potential fecal coliform sources and daily fecal coliform production by source in Stony Creek watershed.

Potential Source	Population in Watershed	Fecal coliform produced ($\times 10^6$ cfu/head-day)
Humans	5,501	1,950 ^a
Dairy cattle		
Milk and dry cows	303	20,200 ^b
Heifers ^c	225	9,200 ^d
Beef cattle	2,951	20,000
Pets	2,057	450 ^e
Poultry		
Chicken Broilers	985,500	136 ^f
Turkey Toms	89,500	93 ^f
Sheep		
Ewes	347	12,000 ^f
Lambs	694	
Horses	179	420 ^f
Deer	4,123	350
Raccoons	1,931	50
Muskrats	332	25 ^g
Beavers	84	0.2
Wild Turkeys	714	93 ^f
Ducks	1,294	800
Geese	1,578	2,400

^a Source: Geldreich *et al.* (1978)

^b Based on data presented by Metcalf and Eddy (1979) and ASAE (1998)

^c Includes calves

^d Based on weight ratio of heifer to milk cow weights and fecal coliform produced by milk cow

^e Source: Weiskel *et al.* (1996)

^f Source: ASAE (1998)

^g Source: Yagow (2001)

4.2.1. Humans and Pets

The Stony Creek watershed has an estimated population of 5,501 people (2,058 households at an average of 2.45 people per household; actual people per household varies by sub-watershed). Fecal coliform from humans can be transported to streams from failing septic systems or via straight pipes discharging directly into streams.

4.1.1.a. Failing Septic Systems

Septic system failure can be evidenced by the rise of effluent to the soil surface. Surface runoff can transport the effluent containing fecal coliform to receiving waters. There were no sewered areas in the Stony Creek watershed. Septic system failure can be evidenced by the rise of effluent to the soil surface. Surface runoff can transport the effluent containing fecal coliform to receiving waters. Unsewered housing age was determined from the 2000 Census of Population and Housing Tables. The census data were analyzed at the block group level and an area weighting method was used to calculate the number of homes in a sub-watershed. Tab number H34 in Summary File 3 of the 2000 Census classifies homes into nine classes based on the age of the structure. For watershed characterization and modeling purposes houses were defined in three categories: *old homes*, built before 1969; *middle-aged homes*, built between 1970 and 1989; and *new homes*, built after 1990. Each age category was calculated as a percent of the total number of homes in a given sub-watershed. Professional judgment was applied in assuming that septic system failure rates for houses in the *old homes*, *middle-aged homes*, and *new homes* categories were 40, 20, and 3%, respectively (R.B. Reneau, personal communication, 3 December 1999, Blacksburg, Va.). Estimates of these failure rates were also supported by the Holmans Creek Watershed Study (a tributary to the North Fork of the Shenandoah River), which found that over 30% of all septic systems checked in the watershed were either failing or not functioning at all (SAIC, 2001).

Daily total fecal coliform load to the land from a failing septic system in a particular sub-watershed was determined by multiplying the average occupancy rate for that sub-watershed (occupancy rate ranged from 1.11 to 4.66 persons per household (Census Bureau, 2000)) by the per capita fecal coliform production rate of 1.95×10^9 cfu/day (Geldreich et al., 1978). Hence, the total fecal coliform loading to the land from a single failing septic system in a sub-watershed with an occupancy rate of 1.11 persons/household was 2.15×10^9 cfu/day. Transport of some portion of the fecal coliform to a stream by runoff

may occur. The number of failing septic systems in the watershed is given in Table 4.3.

4.1.1.b. Straight Pipes

Of the houses located within 150 ft of streams, in the *old* and *middle-aged* categories, 10%, and 2%, respectively, were estimated to have straight pipes (R.B. Reneau, personal communication, 3 December 1999, Blacksburg, Va.).

4.1.1.c. Pets

Assuming one pet per household, there are 1,975 pets in Stony Creek watershed. A dog produces fecal coliform at a rate of 0.45×10^9 cfu/day (Weiskel et al., 1996); this was assumed to be representative of a 'unit pet' – one dog or several cats. The pet population distribution among the sub-watersheds is listed in Table 4.3. Pet waste is generated in the rural residential and urban residential land use types. Surface runoff can transport bacteria in pet waste from residential areas to the stream.

Table 4.17. Estimated number of unsewered houses by age category, number of failing septic systems, and pet population in Mill Creek watershed.

Sub-watershed	Unsewered houses in each age category (no.)			Failing septic systems (no.)	Pet population ^a	Straight Pipes
	Oldest	Mid-Age	Newest			
SC-29	169	120	50	93	339	0
SC-30	32	15	8	16	55	0
SC-31	29	14	7	15	50	0
SC-32	128	65	23	65	216	2
SC-34	94	69	23	52	186	2
SC-37	56	45	20	32	121	6
SC-38	38	27	11	21	76	0
SC-39	43	35	12	25	90	4
SC-40	45	36	12	26	93	4
SC-41	29	41	15	20	85	4
SC-42	13	19	7	9	39	4
SC-43	33	48	17	23	98	4
SC-46	26	38	14	18	78	4
SC-47	7	11	4	5	22	4
SC-48	13	39	12	13	64	0
SC-50	17	47	15	17	79	0
SC-51	7	19	6	7	32	0
SC-52	8	23	7	8	38	0
SC-54	12	34	11	12	57	0
SC-55	32	95	30	33	157	0
Total	831	840	304	510	1975	38

^a Assumed an average of one pet per household.

4.2.2. Cattle

Fecal coliform in cattle waste can be directly excreted to the stream, or it can be transported to the stream by surface runoff from animal waste deposited on pastures or applied to crop, pasture, and hay land.

4.1.2.a. Distribution of Dairy and Beef Cattle in the Stony Creek Watershed

There are 3 dairy farms in the watershed, based on reconnaissance and information from VDACS. From communication with local dairy farmers, it was determined that there are 240 milk cows, 63 dry cows, and 225 heifers in the watershed (Table 4.2). The dairy cattle population was distributed among the

sub-watersheds based on the location of the dairy farms. Table 4.4 shows the number of dairy operations for each sub-watershed.

Table 4.18. Distribution of dairy cattle, dairy operations and beef cattle among Stony Creek sub-watersheds.

Sub-watershed	Dairy cattle	No. of dairy operations	Beef cattle
SC-29	68	1	290
SC-30	0	0	71
SC-31	0	0	49
SC-32	0	0	511
SC-34	200	1	593
SC-37	0	0	313
SC-38	0	0	159
SC-39	0	0	167
SC-40	260	1	247
SC-41	0	0	20
SC-42	0	0	25
SC-43	0	0	171
SC-46	0	0	12
SC-47	0	0	43
SC-48	0	0	50
SC-50	0	0	102
SC-51	0	0	26
SC-52	0	0	23
SC-54	0	0	15
SC-55	0	0	65
Total	528	3	2,952

Beef cattle in the watershed included cow/calf and feeder operations. The exact number of beef operations in the watershed is not known; the beef cattle population (2,952 cattle) in the watershed was estimated using the same procedure outlined in Section 4.1.2. Cows on pastures that are contiguous to streams (1,105 acres for all sub-watersheds, Table 4.19) have stream access.

Table 4.19. Pasture acreages contiguous to stream.

Sub-watershed	Pasture Area (ac)	%^a	Pasture Area Contiguous to Streams (ac)
SC-29	1,894	13%	237
SC-30	467	2%	9
SC-31	318	14%	43
SC-32	3,338	15%	508
SC-34	3,873	10%	388
SC-37	2,046	26%	523
SC-38	1,039	7%	73
SC-39	1,090	3%	35
SC-40	1,613	6%	89
SC-41	130	9%	11
SC-42	164	36%	59
SC-43	1,116	7%	73
SC-46	78	21%	16
SC-47	283	40%	114
SC-48	328	30%	100
SC-50	665	19%	126
SC-51	170	45%	75
SC-52	149	16%	24
SC-54	99	39%	39
SC-55	426	39%	168
Total	19,284	14%	2,711

^a Percent of area contiguous to stream to the total pasture area of that type in that sub-watershed.

A sample calculation for determining the distribution of cattle to different land use types and to the stream is shown in Appendix B. The resulting numbers of cattle in each land use type as well as in the stream for all sub-watersheds are given in Table 4.20 for dairy cattle and in Table 4.21 for beef cattle.

Table 4.20. Distribution of the dairy cattle^a population.

Month	Confined	Pasture	Streams^b
January	190	338	0
February	190	338	0
March	75	453	0
April	75	453	0
May	75	453	0
June	75	453	0
July	75	453	0
August	75	453	0
September	75	453	0
October	75	453	0
November	75	453	0
December	190	338	0

^a Includes milk cows, dry cows, and heifers.

^b Number of dairy cattle defecating in stream.

Table 4.21. Distribution of the beef cattle population.

Months	Confined	Pasture	Stream^a
January	1,358	2,035	2
February	1,594	2,389	2
March	0	4,098	5
April	0	4,214	7
May	0	4,328	12
June	0	4,430	28
July	0	4,547	28
August	0	4,665	29
September	0	4,799	13
October	0	2,947	5
November	0	3,095	4
December	1,299	1,947	2

^a Number of beef cattle defecating in stream.

4.1.2.b. Direct Manure Deposition in Streams

Direct manure loading to streams is due to beef cattle (Table 4.21) defecating in the stream. However, only cattle on pastures contiguous to streams have stream access. Manure loading increases during the warmer months when cattle spend more time in water, compared to the cooler months. Average annual manure loading directly deposited by cattle in the stream for the watershed is 251,620 lb. Daily fecal coliform loading due to cows depositing in the stream, averaged over the year, is 3.79×10^{11} cfu/day. Part of the fecal coliform deposited in the stream stays suspended while the remainder adsorbs to the sediment in the streambed. Under base flow conditions, it is likely that suspended fecal coliform bacteria are the primary form transported with the flow. Sediment-bound fecal coliform bacteria are likely to be re-suspended and transported to the watershed outlet under high flow conditions. Die-off of fecal coliform in the stream depends on sunlight, predation, turbidity, and other environmental factors.

4.1.2.c. Direct Manure Deposition on Pastures

Dairy (Table 4.20) and beef (Table 4.21) cattle that graze on pastures but do not deposit in streams contribute the majority of fecal coliform loading on pastures. Manure loading on pasture was estimated by multiplying the total number of each type of cattle (milk cow, dry cow, heifer, and beef) on pasture by the amount of manure produced per day. The total amount of manure produced by all types of cattle was divided by the pasture acreage to obtain manure loading (lb/ac-day) on pasture. Fecal coliform loading (cfu/ac-day) on pasture was calculated by multiplying the manure loading (lb/ac-day) by the fecal coliform content (cfu/lb) of the manure. Because the confinement schedule of the cattle changes with season, manure and fecal coliform loading on pasture also change with season.

Average annual cattle manure loadings to pasture were 10,189 lb/ac-year. Fecal coliform loadings from cattle on a daily basis, averaged over the year, are 5.44×10^7 cfu/ac-day for pasture. Fecal coliform bacteria deposited on the pasture

surface are subject to die-off due to desiccation and ultraviolet (UV) radiation. Runoff can transport part of the remaining fecal coliform to receiving waters.

4.1.2.d. Land Application of Liquid Dairy Manure

A typical milk cow weighs 1,400 lb and produces 17 gallons of liquid manure daily (ASAE, 1998). Based on the monthly confinement schedule (Table 4.20) and the number of milk cows (Table 4.16), annual liquid dairy manure production in the watershed is 7.0 million gallons. Based on per capita fecal coliform production of milk cows, the fecal coliform concentration in fresh liquid dairy manure is 1.18×10^9 cfu/gal. Liquid dairy manure receives priority over other manure types (poultry litter and solid cattle manure) when applied to land. Liquid dairy manure application rates are 6,600 and 3,900 gal/ac-year to cropland and pasture land use categories, respectively, with cropland receiving priority in application. Based on availability of land and liquid dairy manure, as well as the assumptions regarding application rates and priority of application, it was estimated that liquid dairy manure was applied to 57 acres (10%) of cropland. Because there was more than enough crop area to receive the liquid manure produced in the watershed, no liquid dairy manure was applied to pasture.

The typical crop rotation in the watershed is a seven-year rotation with three years of corn-rye and four years of rotational hay. It was assumed that 50% of the corn acreage was under no-till cultivation. Liquid manure is applied to cropland during February through May (prior to planting) and in October-November (after the crops are harvested). For spring application to cropland, liquid manure is applied on the soil surface to rotational hay and no-till corn, and is incorporated into the soil for corn in conventional tillage. In fall, liquid manure is incorporated into the soil for cropland under rye, and surface-applied to cropland under rotational hay. In all months except December and January, liquid manure can be surface-applied to pasture. It was assumed that only 10% of the subsurface-applied fecal coliform was available for removal in surface runoff based on local knowledge. The application schedule of liquid manure is

given in Table 4.22. Dry cows and heifers were assumed to produce only solid manure.

Table 4.22. Schedule of cattle and poultry waste application in the Stony Creek watershed.

Month	Liquid manure applied (%) ^a		Solid manure or poultry litter applied (%) ^a	
	Crops	Pasture	Crops	Pasture
January	0	0	0	0
February	7.1	5	6.7	5
March	35.7	25	33.3	25
April	28.6	20	26.7	20
May	7.1	5	6.7	5
June	0	10	0	5
July	0	0	0	5
August	0	5	0	5
September	0	15	0	10
October	7.1	5	13.3	10
November	14.3	10	13.3	10
December	0	0	0	0

^a As percent of annual load applied to each land use type.

4.1.2.e. Land Application of Solid Manure

Solid manure produced by dry cows, heifers, and beef cattle during confinement is collected for land application. It was assumed that milk cows produce only liquid manure while in confinement. The number of cattle, their typical weights, amounts of solid manure produced, and fecal coliform concentration in fresh manure are given in Table 4.23. Solid manure is last on the priority list for application to land (it falls behind liquid manure and poultry litter). The amount of solid manure produced in each sub-watershed was estimated based on the populations of dry cows, heifers, and beef cattle in the sub-watershed (Table 4.18) and their confinement schedules (Table 4.20, Table 4.21). Solid manure from dry cows, heifers, and beef cattle contained different fecal coliform concentrations (cfu/lb) (Table 4.23).

Table 4.23. Estimated population of dry cows, heifers, and beef cattle, typical weights, per capita solid manure production, and fecal coliform concentration in fresh solid manure in individual cattle type.

Type of cattle	Population	Typical weight (lb)	Solid manure produced (lb/animal-day)	Fecal coliform concentration in fresh manure ($\times 10^6$ cfu/lb)
Dry cow	63	1,400 ^a	115.0 ^b	176 ^c
Heifer	225	640 ^d	40.7 ^a	226 ^c
Beef	2,952	1,000 ^e	60.0 ^b	333 ^c

^a Source: ASAE (1998)

^b Source: MWPS (1993)

^c Based on per capita fecal coliform production per day (Table 4.16) and manure production

^d Based on weighted average weight assuming that 57% of the animals are older than 10 months (900 lb ea.), 28% are 1.5-10 months (400 lb ea.) and the remainder are less than 1.5 months (110 lb ea.) (MWPS, 1993).

^e Based on input from local producers

Solid manure is applied at the rate of 12 tons/ac-year to both cropland and pasture, with priority given to cropland. As in the case of liquid manure, solid manure is only applied to cropland during February through May, October, and November. Solid manure can be applied to pasture during the whole year, except December and January. The method of application of solid manure to cropland or pasture is assumed to be identical to the method of application of liquid dairy manure. The application schedule for solid manure is given in Table 4.22. Based on availability of land and solid manure, as well as the assumptions regarding application rates and priority of application, it was estimated that solid cattle manure was applied to 122 acres (21%) of the cropland and 221 acres (7%) of pasture.

4.2.3. Poultry

The poultry population (Table 4.16) was estimated based on the permitted combined feeding operations (CAFO) located within the watershed and discussions with local producers and nutrient management specialists. Poultry litter production was estimated from the poultry population after accounting for the time when the houses are not occupied.

Because poultry is raised entirely in confinement, all litter produced is collected and stored prior to land application. The estimated production rate of poultry litter in the Stony Creek watershed is 1.63×10^7 lb/year, which corresponds to a fecal coliform production rate of 1.64×10^{16} cfu/year. This fecal coliform produced is subject to die-off in storage and losses due to incorporation prior to being subject to transport via runoff. Poultry litter is applied at the rate of 3 tons/ac-year first to cropland, and then to pastures at the same rate. Poultry litter receives priority after all liquid manure has been applied (i.e., it is applied before solid cattle manure is considered). The method of poultry litter application to cropland and pastures is assumed to be identical to the method of cattle manure application. The application schedule of poultry litter is given in Table 4.9. As with liquid and solid manures, poultry litter is not applied to cropland during June through September. Based on availability of land and poultry litter, as well as the assumptions regarding application rates and priority of application, it was estimated that poultry litter was applied to 398 acres (69%) of cropland and 3,788 acres (49%) of pasture.

4.2.4. Sheep

The sheep population (Table 4.16) was estimated based on discussions with nutrient management specialists, observations of the watershed, and discussions with stakeholders. The sheep herd was composed of lambs and ewes. The lamb population was expressed in equivalent sheep numbers. The equivalent sheep population calculated for lambs was based on the assumption that the average weight of a lamb is half of the weight of a sheep. The lamb population for the Stony Creek watershed was estimated to be 694 animals. The equivalent sheep population for the lambs was 347. The total number of sheep for the Stony Creek watershed was the sum of the number of ewes (347), and the equivalent number of lambs (347) for a total of 694 animals. The sheep were kept on pasture. The relative stocking density for sheep was estimated to be 0.6 per acre. The equivalent sheep population for each sub-watershed is shown Table 4.24. Sheep are not usually confined and tend not to wade or defecate in

the streams. Therefore, the fecal coliform produced by sheep was added to the loads applied to pasture.

Table 4.24. Sheep Populations in Stony Creek Sub-Watersheds.

Sub-watershed	Ewe Population	Lamb Population
SC-29	34	68
SC-30	8	16
SC-31	6	12
SC-32	60	120
SC-34	69	138
SC-37	37	74
SC-38	19	38
SC-39	20	40
SC-40	29	58
SC-41	2	4
SC-42	3	6
SC-43	20	40
SC-46	1	2
SC-47	5	10
SC-48	6	12
SC-50	12	24
SC-51	3	6
SC-52	3	6
SC-54	2	4
SC-55	8	16
Total	347	694

Pasture has average annual sheep manure loadings of 78 lb/ac-year. Fecal coliform loadings for pasture from sheep on a daily basis averaged over the year are 1.07×10^9 cfu/ac-day.

4.2.5. Horses

Horse populations for the Stony Creek watershed were obtained through observations of the watershed and communication with local producers. The total horse population was estimated to be 179. The distribution of horse population among the sub-watersheds is listed in Table 4.25. Horses are not usually confined and tend not to wade or defecate in the streams. Therefore, the fecal coliform produced by horses was added to the loads applied to pasture.

Fecal coliform loadings from horses on a daily basis averaged over the year and over pasture areas in the entire watershed are 9.64×10^6 cfu/ac-day.

Table 4.25. Horse Populations among Stony Creek Sub-Watersheds.

Sub-watershed	Horse Population
SC-29	17
SC-30	4
SC-31	3
SC-32	31
SC-34	36
SC-37	19
SC-38	10
SC-39	10
SC-40	15
SC-41	1
SC-42	2
SC-43	10
SC-46	1
SC-47	3
SC-48	3
SC-50	6
SC-51	2
SC-52	1
SC-54	1
SC-55	4
Total	179

4.2.6. Wildlife

Wildlife fecal coliform contributions can be from excretion of waste on land and from excretion directly into streams. Information provided by VADGIF, professional trappers, and watershed residents were used to estimate wildlife populations. Wildlife species that were found in quantifiable numbers in the watershed included deer, raccoon, muskrat, beaver, wild turkey, goose, and wood duck. Population numbers for each species and fecal coliform amounts were determined (Table 4.16) along with preferred habitat and habitat area (Table 4.26).

Professional judgment was used in estimating the percent of each wildlife species depositing directly into streams, considering the habitat area each occupied (Table 4.26). Fecal matter produced by deer that is not directly deposited in streams is distributed among pastures and forest. Raccoons

deposit their waste in streams and forests. Muskrats deposit their waste in streams, forest, pasture, and cropland.

Fecal loading from wildlife was estimated for each sub-watershed. The wildlife populations were distributed among the sub-watersheds based on the area of appropriate habitat in each sub-watershed. For example, the deer population was evenly distributed across the watershed, whereas the length of stream and impoundment shorelines determined the muskrat population. Therefore, a sub-watershed with more stream length and impoundments would have more muskrats than a sub-watershed with shorter stream length and fewer impoundments, and less area in forest and crop land use. Distribution of wildlife among sub-watersheds is given in Table 4.27.

Table 4.26. Wildlife habitat description and acreage, and percent direct fecal deposition in streams.

Wildlife type	Habitat	Acres of habitat	Population Density (animal/ac-habitat)	Direct fecal deposition in streams (%)
Deer	Entire Watershed	87,723	0.047	0.5%
Raccoon	low density on forests not in high density area; high density on forest within 600 ft of a permanent water source or 0.5 mile of cropland	27,586	Low density: 10 High density: 30	5%
Muskrat	16/mile of ditch or medium sized stream intersecting cropland; 8/mile of ditch or medium sized stream intersecting pasture; 10/mile of pond or lake edge; 50/mile of slow-moving river edge	121	-see habitat column-	12.5%
Beaver	300 ft buffer streams and impoundments in forest and pasture	5,600	0.015	25%
Geese	300 ft buffer around main streams	5,340	0.078 - off season 0.1092 - peak season	12.5%
Wood Duck	300 ft buffer around main streams	5,812	0.0624 - off season 0.0936 - peak season	12.5%
Wild Turkey	Entire Watershed except residential	71,400	0.01	5%

Table 4.27. Distribution of wildlife among sub-watersheds.

Sub-watershed	Deer	Raccoon	Muskrat	Beaver	Geese	Wood Duck	Wild Turkey
SC-29	147	26	13	2	33	28	28
SC-30	33	7	1	0	5	4	6
SC-31	26	5	2	1	10	8	4
SC-32	220	24	23	4	46	39	46
SC-34	288	48	18	4	46	38	60
SC-37	205	52	25	5	58	48	43
SC-38	79	13	3	1	12	10	16
SC-39	88	18	2	1	7	6	18
SC-40	300	86	4	2	23	19	63
SC-41	320	93	5	4	46	38	68
SC-42	143	52	3	2	25	20	31
SC-43	252	87	5	4	50	42	54
SC-46	206	61	1	3	35	30	44
SC-47	59	18	7	2	17	14	13
SC-48	157	51	6	2	21	17	33
SC-50	194	70	5	2	27	22	41
SC-51	787	31	3	2	19	15	17
SC-52	93	35	1	1	16	13	20
SC-54	142	44	15	2	24	20	30
SC-55	384	149	30	3	47	39	79
Total	4,123	970	172	47	567	470	714

4.2.7. Summary: Contribution from All Sources

Based on the inventory of sources discussed in this chapter, a summary of the contribution by the different nonpoint sources to direct annual fecal coliform loading to the streams is given in Table 4.28. Distribution of annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Table 4.28.

From Table 4.28, it is clear that nonpoint source loadings to the land surface are 170 times larger than direct loadings to the streams (not including commercial sources), with pastures receiving about 97% of the total fecal coliform load. It is premature to assume that most of the fecal coliform loading in streams originates from upland sources, primarily from pastures. Other factors such as precipitation amount and pattern, size of runoff events, manure application activities (time and method), type of waste (solid versus liquid manure), and proximity to streams also impact the amount of fecal coliform from upland areas that reaches the streams. The HSPF model considers these factors when estimating fecal

coliform loads to the receiving waters, as described in Chapter 5.

Table 4.28. Annual fecal coliform loadings to the stream and the various land use categories in the Stony Creek watershed.

Source	Fecal coliform loading (x10 ¹² cfu/year)	Percent of total loading
Direct loading to streams		
Cattle in stream	138	<1%
Wildlife in stream	151	<1%
Straight pipes	20	<1%
Loading to land surfaces		
Cropland	282	<1%
Pasture	52,488	97%
Residential ^a	45	<1%
Forest	858	2%
Total	53,673	

^a Includes loads received from both High and Low Density Residential due to failed septic systems and pets.

4.3. North Fork of the Shenandoah River Sources

A synopsis of the fecal coliform sources characterized and accounted for in the North Fork of the Shenandoah River watershed, along with average fecal coliform production rates are shown in Table 4.29.

Table 4.29. Potential fecal coliform sources and daily fecal coliform production by source in North Fork Shenandoah River watershed.

Potential Source	Population in Watershed	Fecal coliform produced ($\times 10^6$ cfu/head-day)
Humans	26,991	1,950 ^a
Dairy cattle		
Milk and dry cows	928	20,200 ^b
Heifers ^c	744	9,200 ^d
Beef cattle	10,793	20,000
Pets	10,823	450 ^e
Poultry		
Chicken Broilers	4,452,130	136 ^f
Turkey Toms	725,200	93 ^f
Sheep		
Ewes	1,423	12,000 ^f
Lambs	2,846	
Horses	789	420 ^f
Deer	6,900	350
Raccoons	708	50
Muskrats	128	25 ^g
Beavers	23	0.2
Wild Turkeys	1,400	93 ^f
Ducks	572	800
Geese	477	2,400

^a Source: Geldreich *et al.* (1978)

^b Based on data presented by Metcalf and Eddy (1979) and ASAE (1998)

^c Includes calves

^d Based on weight ratio of heifer to milk cow weights and fecal coliform produced by milk cow

^e Source: Weiskel *et al.* (1996)

^f Source: ASAE (1998)

^g Source: Yagow (2001)

4.3.1. Humans and Pets

The North Fork Shenandoah River watershed has an estimated population of 26,991 people (10,826 households at an average of 2.49 people per household; actual people per household varies by sub-watershed). Fecal coliform from humans can be transported to streams from failing septic systems or via straight pipes discharging directly into streams.

4.1.1.a. Failing Septic Systems

Septic system failure can be evidenced by the rise of effluent to the soil surface. Surface runoff can transport the effluent containing fecal coliform to receiving waters. There are approximately 2,547 households that have sewer

service in the North Fork Shenandoah River watershed. The human bacteria load from the sewer households was accounted for through the permitted discharges for the municipal treatment facilities in the watershed. The remaining 8,276 households did not have sewer service and were considered to have on-site disposal, such as septic systems. Septic system failure can be evidenced by the rise of effluent to the soil surface. Surface runoff can transport the effluent containing fecal coliform to receiving waters. Unsewered housing age was determined from the 2000 Census of Population and Housing Tables. The census data were analyzed at the block group level and an area weighting method was used to calculate the number of homes in a sub-watershed. Tab number H34 in Summary File 3 of the 2000 Census classifies homes into nine classes based on the age of the structure. For watershed characterization and modeling purposes houses were defined in three categories: *old homes*, built before 1969; *middle-aged homes*, built between 1970 and 1989; and *new homes*, built after 1990. Each age category was calculated as a percent of the total number of homes in a given sub-watershed. Professional judgment was applied in assuming that septic system failure rates for houses in the *old homes*, *middle-aged homes*, and *new homes* categories were 40, 20, and 3%, respectively (R.B. Reneau, personal communication, 3 December 1999, Blacksburg, Va.). Estimates of these failure rates were also supported by the Holmans Creek Watershed Study (a tributary to the North Fork of the Shenandoah River), which found that over 30% of all septic systems checked in the watershed were either failing or not functioning at all (SAIC, 2001).

Daily total fecal coliform load to the land from a failing septic system in a particular sub-watershed was determined by multiplying the average occupancy rate for that sub-watershed (occupancy rate ranged from 1.11 to 4.66 persons per household (Census Bureau, 2000)) by the per capita fecal coliform production rate of 1.95×10^9 cfu/day (Geldreich et al., 1978). Hence, the total fecal coliform loading to the land from a single failing septic system in a sub-watershed with an occupancy rate of 1.11 persons/household was 2.15×10^9 cfu/day. Transport of some portion of the fecal coliform to a stream by runoff

may occur. The number of failing septic systems in the watershed is given in Table 4.30.

4.1.1.b. Straight Pipes

Of the houses located within 150 ft of streams, in the *old* and *middle-aged* categories, 10%, and 2%, respectively, were estimated to have straight pipes (R.B. Reneau, personal communication, 3 December 1999, Blacksburg, Va.).

4.1.1.c. Pets

Assuming one pet per household, there are 10,826 pets in North Fork Shenandoah River watershed. A dog produces fecal coliform at a rate of 0.45×10^9 cfu/day (Weiskel et al., 1996); this was assumed to be representative of a 'unit pet' – one dog or several cats. The pet population distribution among the sub-watersheds is listed in Table 4.3. Pet waste is generated in the farmstead, rural residential and urban residential land use types. Surface runoff can transport bacteria in pet waste from residential areas to the stream.

Table 4.30. Estimated number of unsewered houses by age category, number of failing septic systems, and pet population in North Fork Shenandoah River watershed.

Sub-watershed	Unsewered houses in each age category (no.)			Failing septic systems (no.)	Pet population ^a	Straight Pipes
	Oldest	Mid-Age	Newest			
NFSL-1	407	296	139	92	1,452	0
NFSL-3	252	211	135	35	734	0
NFSL-4	253	158	104	28	515	0
NFSL-5	111	74	37	14	280	0
NFSL-7	288	210	115	51	815	0
NFSL-8	375	270	133	58	1,185	0
NFSL-9	178	158	91	26	566	0
NFSL-10	248	229	129	36	706	1
NFSL-12	545	306	148	58	999	0
NFSL-14	25	14	6	2	45	0
NFSL-16	148	125	57	18	373	0
NFSL-17	233	206	99	43	729	0
NFSL-18	316	236	142	54	1,098	0
NFSL-19	138	88	48	25	423	0
NFSL-20	72	45	22	10	165	0
NFSL-21	22	16	8	5	96	0
NFSL-22	36	23	14	6	109	0
NFSL-24	73	39	24	10	173	0
NFSL-26	124	91	44	16	269	1
NFSL-27	40	28	18	6	94	0
Total	3,884	2,823	1,513	595	10,826	2

^a Assumed an average of one pet per household and these also include sewerred households.

4.3.2. Cattle

Fecal coliform in cattle waste can be directly excreted to the stream, or it can be transported to the stream by surface runoff from animal waste deposited on pastures or applied to crop, pasture, and hay land.

4.1.2.a. Distribution of Dairy and Beef Cattle in the North Fork Shenandoah River Watershed

There are 7 dairy farms in the watershed, based on reconnaissance and information from VDACS. From communication with local dairy farmers, it was determined that there are 822 milk cows, 106 dry cows, and 744 heifers in the watershed (Table 4.29). Two of the dairy farms were personally contacted; the remaining 5 farm populations were estimated based on the average size of all

dairy farms contacted for Mill, Stony, and Lower North Fork during TMDL development. The dairy cattle population was distributed among the sub-watersheds based on the location of the dairy farms. Table 4.31 shows the number of dairy operations for each sub-watershed.

Table 4.31. Distribution of dairy cattle, dairy operations and beef cattle among North Fork Shenandoah River sub-watersheds.

Sub-watershed	Dairy cattle	No. of dairy operations	Beef cattle
NFSL-1	0	0	396
NFSL-3	160	1	985
NFSL-4	0	0	736
NFSL-5	0	0	338
NFSL-7	0	0	744
NFSL-8	160	1	502
NFSL-9	0	0	298
NFSL-10	272	1	890
NFSL-12	0	0	1,142
NFSL-14	0	0	43
NFSL-16	440	1	854
NFSL-17	0	0	779
NFSL-18	320	1	1,052
NFSL-19	0	0	601
NFSL-20	160	1	351
NFSL-21	160	1	74
NFSL-22	0	0	188
NFSL-24	0	0	328
NFSL-26	0	0	364
NFSL-27	0	0	128
Total	1,672	7	10,793

Beef cattle in the watershed included cow/calf and feeder operations. The exact number of beef operations in the watershed is not known; the beef cattle population (10,793 cattle) in the watershed was estimated using the same procedure outlined in Section 4.1.2. Beef cows on pastures that are contiguous to streams (6,893 acres for all sub-watersheds, Table 4.32) have stream access.

Table 4.32. Pasture acreages contiguous to stream.

Sub-watershed	Pasture Area (ac)	%^a	Pasture Area Contiguous to Streams (ac)
NFSL-1	2,587	14%	362
NFSL-3	6,436	17%	1,094
NFSL-4	4,807	11%	529
NFSL-5	2,211	16%	354
NFSL-7	4,858	8%	389
NFSL-8	3,278	7%	229
NFSL-9	1,948	17%	331
NFSL-10	5,818	10%	582
NFSL-12	7,463	7%	522
NFSL-14	284	16%	45
NFSL-16	5,583	7%	391
NFSL-17	5,311	3%	159
NFSL-18	7,209	10%	721
NFSL-19	4,100	2%	82
NFSL-20	2,403	12%	288
NFSL-21	509	10%	51
NFSL-22	1,287	5%	64
NFSL-24	2,250	14%	315
NFSL-26	2,494	10%	249
NFSL-27	877	19%	167
Total	71,715	10%	6,926

^a Percent of area contiguous to stream to the total pasture area of that type in that sub-watershed.

A sample calculation for determining the distribution of cattle to different land use types and to the stream is shown in Appendix B. The resulting numbers of cattle in each land use type as well as in the stream for all sub-watersheds are given in Table 4.33 for dairy cattle and in Table 4.34 for beef cattle.

Table 4.33. Distribution of the dairy cattle^a population.

Month	Confined	Pasture	Streams^b
January	957	716	0
February	957	716	0
March	329	1,343	0
April	247	1,425	0
May	247	1,425	0
June	247	1,425	0
July	247	1,425	0
August	247	1,425	0
September	247	1,425	0
October	247	1,425	0
November	329	1,343	0
December	957	716	0

^a Includes milk cows, dry cows, and heifers.

^b Number of dairy cattle defecating in stream.

Table 4.34. Distribution of the beef cattle population.

Months	Confined	Pasture	Stream^a
January	4,965	7,443	5
February	5,828	8,737	5
March	0	14,989	14
April	0	15,415	19
May	0	15,837	29
June	0	16,228	69
July	0	16,658	71
August	0	17,088	73
September	0	17,561	32
October	0	10,780	13
November	0	11,322	10
December	4,749	7,119	4

^a Number of beef cattle defecating in stream.

4.1.2.b. Direct Manure Deposition in Streams

Direct manure loading to streams is due to beef cattle (Table 4.34) defecating in the stream. However, only cattle on pastures contiguous to streams have stream access. Manure loading increases during the warmer months when cattle spend more time in water, compared to the cooler months. Average annual manure loading directly deposited by cattle in the stream for the watershed is 629,472 lb. Daily fecal coliform loading due to cows depositing in the stream, averaged over the year, is 9.48×10^{11} cfu/day. Part of the fecal coliform deposited in the stream stays suspended while the remainder adsorbs to the sediment in the streambed. Under base flow conditions, it is likely that suspended fecal coliform bacteria are the primary form transported with the flow. Sediment-bound fecal coliform bacteria are likely to be re-suspended and transported to the watershed outlet under high flow conditions. Die-off of fecal coliform in the stream depends on sunlight, predation, turbidity, and other environmental factors.

4.1.2.c. Direct Manure Deposition on Pastures

Dairy (Table 4.33) and beef (Table 4.34) cattle that graze on pastures but do not deposit in streams contribute the majority of fecal coliform loading on pastures. Manure loading on pasture was estimated by multiplying the total number of each type of cattle (milk cow, dry cow, heifer, and beef) on pasture by the amount of manure produced per day. The total amount of manure produced by all types of cattle was divided by the pasture acreage to obtain manure loading (lb/ac-day) on pasture. Fecal coliform loading (cfu/ac-day) on pasture was calculated by multiplying the manure loading (lb/ac-day) by the fecal coliform content (cfu/lb) of the manure. Because the confinement schedule of the cattle changes with season, manure and fecal coliform loading on pasture also change with season.

Average annual cattle manure loadings to pasture were 4,528 lb/ac-year. Fecal coliform loadings from cattle to pasture on a daily basis, averaged over the year, are 6.91×10^9 cfu/ac-day. Fecal coliform bacteria deposited on the pasture

surface are subject to die-off due to desiccation and ultraviolet (UV) radiation. Runoff can transport part of the remaining fecal coliform to receiving waters.

4.1.2.d. Land Application of Liquid Dairy Manure

A typical milk cow weighs 1,400 lb and produces 17 gallons of liquid manure daily (ASAE, 1998). Based on the monthly confinement schedule (Table 4.33, Table 4.34) and the number of milk cows (Table 4.29), annual liquid dairy manure production in the watershed is 3.7 million gallons. Based on per capita fecal coliform production of milk cows, the fecal coliform concentration in fresh liquid dairy manure is 1.18×10^9 cfu/gal. Liquid dairy manure receives priority over other manure types (poultry litter and solid cattle manure) when applied to land. Liquid dairy manure application rates are 6,600 and 3,900 gal/ac-year to cropland and pasture land use categories, respectively, with cropland receiving priority in application. Based on availability of land and liquid dairy manure, as well as the assumptions regarding application rates and priority of application, it was estimated that liquid dairy manure was applied to 331 acres (5%) of cropland. Because there was more than enough crop area to receive the liquid manure produced in the watershed, no liquid dairy manure was applied to pasture.

The typical crop rotation in the watershed is a seven-year rotation with three years of corn-rye and four years of rotational hay. It was assumed that 50% of the corn acreage was under no-till cultivation. Liquid manure is applied to cropland during February through May (prior to planting) and in October-November (after the crops are harvested). For spring application to cropland, liquid manure is applied on the soil surface to rotational hay and no-till corn, and is incorporated into the soil for corn in conventional tillage. In fall, liquid manure is incorporated into the soil for cropland under rye, and surface-applied to cropland under rotational hay. In all months except December and January, liquid manure can be surface-applied to pasture. It was assumed that only 10% of the subsurface-applied fecal coliform was available for removal in surface runoff based on local knowledge. The application schedule of liquid manure is

given in Table 4.35. Dry cows and heifers were assumed to produce only solid manure.

Table 4.35. Schedule of cattle and poultry waste application in the North Fork Shenandoah River watershed.

Month	Liquid manure applied (%) ^a		Solid manure or poultry litter applied (%) ^a	
	Crops	Pasture	Crops	Pasture
January	0	0	0	0
February	7.1	5	6.7	5
March	35.7	25	33.3	25
April	28.6	20	26.7	20
May	7.1	5	6.7	5
June	0	10	0	5
July	0	0	0	5
August	0	5	0	5
September	0	15	0	10
October	7.1	5	13.3	10
November	14.3	10	13.3	10
December	0	0	0	0

^a As percent of annual load applied to each land use type.

4.1.2.e. Land Application of Solid Manure

Solid manure produced by dry cows, heifers, and beef cattle during confinement is collected for land application. It was assumed that milk cows produce only liquid manure while in confinement. The number of cattle, their typical weights, amounts of solid manure produced, and fecal coliform concentration in fresh manure are given in Table 4.36. Solid Manure is last on the priority list for application to land (it falls behind liquid manure and poultry litter). The amount of solid manure produced in each sub-watershed was estimated based on the populations of dry cows, heifers, and beef cattle in the sub-watershed (Table 4.31) and their confinement schedules (Table 4.33, Table 4.34). Solid manure from dry cows, heifers, and beef cattle contained different fecal coliform concentrations (cfu/lb) (Table 4.36).

Table 4.36. Estimated population of dry cows, heifers, and beef cattle, typical weights, per capita solid manure production, and fecal coliform concentration in fresh solid manure in individual cattle type.

Type of cattle	Population	Typical weight (lb)	Solid manure produced (lb/animal-day)	Fecal coliform concentration in fresh manure ($\times 10^6$ cfu/lb)
Dry cow	106	1,400 ^a	115.0 ^b	176 ^c
Heifer	744	640 ^d	40.7 ^a	226 ^c
Beef	10,793	1,000 ^e	60.0 ^b	333 ^c

^a Source: ASAE (1998)

^b Source: MWPS (1993)

^c Based on per capita fecal coliform production per day (Table 4.29) and manure production

^d Based on weighted average weight assuming that 57% of the animals are older than 10 months (900 lb ea.), 28% are 1.5-10 months (400 lb ea.) and the remainder are less than 1.5 months (110 lb ea.) (MWPS, 1993).

^e Based on input from local producers

Solid manure is applied at the rate of 12 tons/ac-year to both cropland and pasture, with priority given to cropland. As in the case of liquid manure, solid manure is only applied to cropland during February through May, October, and November. Solid manure can be applied to pasture during the whole year, except December and January. The method of application of solid manure to cropland or pasture is assumed to be identical to the method of application of liquid dairy manure. The application schedule for solid manure is given in Table 4.35. Based on availability of land and solid manure, as well as the assumptions regarding application rates and priority of application, it was estimated that solid cattle manure was applied to 238 acres (4%) of the cropland and 990 acres (2%) of pasture.

4.3.3. Poultry

The poultry population (Table 4.29) was estimated based on the permitted combined feeding operations (CAFO) located within the watershed and discussions with local producers and nutrient management specialists. Poultry litter production was estimated from the poultry population after accounting for the time when the houses are not occupied.

Because poultry is raised entirely in confinement, all litter produced is collected and stored prior to land application. The estimated production rate of poultry litter in the North Fork Shenandoah River watershed is 1.63×10^7 lb/year, which corresponds to a fecal coliform production rate of 1.64×10^{16} cfu/year. This fecal coliform produced is subject to die-off in storage and losses due to incorporation prior to being subject to transport via runoff. Poultry litter is applied at the rate of 3 tons/ac-year first to cropland, and then to pastures at the same rate. Poultry litter receives priority after all liquid manure has been applied (i.e., it is applied before solid cattle manure is considered). The method of poultry litter application to cropland and pastures is assumed to be identical to the method of cattle manure application. The application schedule of poultry litter is given in Table 4.35. As with liquid and solid manures, poultry litter is not applied to cropland during June through September. Based on availability of land and poultry litter, as well as the assumptions regarding application rates and priority of application, it was estimated that poultry litter was applied to 5,660 acres (91%) of cropland; 18,276 acres (26%) of pasture.

4.3.4. Sheep

The sheep population (Table 4.29) was estimated based on discussions with nutrient management specialists, observations of the watershed, and discussions with stakeholders. The sheep herd was composed of lambs and ewes. The lamb population was expressed in equivalent sheep numbers. The equivalent sheep population calculated for lambs was based on the assumption that the average weight of a lamb is half of the weight of a sheep. The lamb population for the North Fork Shenandoah River watershed was estimated to be 2,846 animals. The equivalent sheep population for the lambs was 1,423. The total number of sheep for the North Fork Shenandoah River watershed was the sum of the number of ewes (1,423), and the equivalent number of lambs (1,423) for a total of 2,846 animals. The sheep were kept on pasture. The relative stocking density for sheep was estimated to be 0.6 per acre. The equivalent sheep population for each sub-watershed is shown Table 4.37. Sheep are not

usually confined and tend not to wade or defecate in the streams. Therefore, the fecal coliform produced by sheep was added to the loads applied to pasture.

Table 4.37. Sheep Populations in North Fork Shenandoah Sub-Watersheds.

Sub-watershed	Ewe Population	Lamb Population
NFSL-1	46	92
NFSL-3	115	230
NFSL-4	86	172
NFSL-5	40	80
NFSL-7	87	174
NFSL-8	59	118
NFSL-9	35	70
NFSL-10	104	208
NFSL-12	134	268
NFSL-14	5	10
NFSL-16	100	200
NFSL-17	121	242
NFSL-18	168	336
NFSL-19	94	188
NFSL-20	56	112
NFSL-21	12	24
NFSL-22	30	60
NFSL-24	53	106
NFSL-26	58	116
NFSL-27	20	40
Total	1,423	2,846

Pasture has average annual sheep manure loadings of 35 lb/ac-year. Fecal coliform loadings for pasture from sheep on a daily basis averaged over the year are 4.82×10^8 cfu/ac-day.

4.3.5. Horses

Horse populations for the North Fork Shenandoah River watershed were obtained through observations of the watershed and communication with local producers. The total horse population was estimated to be 789. The distribution of horse population among the sub-watersheds is listed in Table 4.38. Horses are not usually confined and tend not to wade or defecate in the streams. Therefore, the fecal coliform produced by horses was added to the loads applied to pasture.

Fecal coliform loadings from horses on a daily basis averaged over the year and over pasture areas in the entire watershed are 4.76×10^6 cfu/ac-day.

Table 4.38. Horse Populations among North Fork Shenandoah Sub-Watersheds.

Sub-watershed	Horse Population
NFSL-1	24
NFSL-3	59
NFSL-4	44
NFSL-5	20
NFSL-7	45
NFSL-8	30
NFSL-9	18
NFSL-10	53
NFSL-12	68
NFSL-14	3
NFSL-16	51
NFSL-17	74
NFSL-18	103
NFSL-19	57
NFSL-20	34
NFSL-21	7
NFSL-22	18
NFSL-24	32
NFSL-26	36
NFSL-27	13
Total	789

4.3.6. Wildlife

Wildlife fecal coliform contributions can be from excretion of waste on land and from excretion directly into streams. Information provided by VADGIF, professional trappers, and watershed residents were used to estimate wildlife populations. Wildlife species that were found in quantifiable numbers in the watershed included deer, raccoon, muskrat, beaver, wild turkey, goose, and wood duck. Population numbers for each species and fecal coliform amounts were determined (Table 4.29) along with preferred habitat and habitat area (Table 4.39).

Professional judgment was used in estimating the percent of each wildlife species depositing directly into streams, considering the habitat area each occupied (Table 4.39). Fecal matter produced by deer that is not directly deposited in streams is distributed among pastures and forest. Raccoons

deposit their waste in streams and forests. Muskrats deposit their waste in streams, forest, pasture, and cropland.

Fecal loading from wildlife was estimated for each sub-watershed. The wildlife populations were distributed among the sub-watersheds based on the area of appropriate habitat in each sub-watershed. For example, the deer population was evenly distributed across the watershed, whereas the length of stream and impoundment shoreline determined the muskrat population. Therefore, a sub-watershed with more stream length and impoundments would have more muskrats than a sub-watershed with shorter stream length and fewer impoundments. Distribution of wildlife among sub-watersheds is given in Table 4.40.

Table 4.39. Wildlife habitat description and acreage, and percent direct fecal deposition in streams.

Wildlife type	Habitat	Acres of habitat	Population Density (animal/ac-habitat)	Direct fecal deposition in streams (%)
Deer	Entire Watershed	146,809	0.047	0.5%
Raccoon	low density on forests not in high density area; high density on forest within 600 ft of a permanent water source or 0.5 mile of cropland	40,329	Low density: 10 High density: 30	5%
Muskrat	16/mile of ditch or medium sized stream intersecting cropland; 8/mile of ditch or medium sized stream intersecting pasture; 10/mile of pond or lake edge; 50/mile of slow-moving river edge	186	-see habitat column-	12.5%
Beaver	300 ft buffer streams and impoundments in forest and pasture	6,200	0.015	25%
Geese	300 ft buffer around main streams	16,987	0.078 - off season 0.1092 - peak season	12.5%
Wood Duck	300 ft buffer around main streams	18,157	0.0624 - off season 0.0936 - peak season	12.5%
Wild Turkey	Entire Watershed except urban and farmstead	140,000	0.01	5%

Table 4.40. Distribution of wildlife among sub-watersheds.

Sub-watershed	Deer	Raccoon	Muskrat	Beaver	Geese	Wood Duck	Wild Turkey
NFSL-1	299	43	4	1	31	27	56
NFSL-3	785	105	19	5	99	83	162
NFSL-4	486	53	12	1	40	33	97
NFSL-5	266	36	9	2	41	35	55
NFSL-7	496	56	9	2	34	28	102
NFSL-8	280	32	0	1	22	18	50
NFSL-9	276	38	7	3	43	35	58
NFSL-10	612	66	11	2	47	39	123
NFSL-12	972	92	11	3	60	50	199
NFSL-14	28	2	0	0	5	4	6
NFSL-16	420	27	7	1	31	25	84
NFSL-17	359	21	5	0	12	10	75
NFSL-18	469	28	3	0	29	25	96
NFSL-19	303	24	3	0	9	8	60
NFSL-20	157	10	7	0	14	12	33
NFSL-21	40	4	2	0	7	5	7
NFSL-22	83	4	2	0	5	4	17
NFSL-24	169	14	7	1	17	14	36
NFSL-26	289	36	6	0	14	12	61
NFSL-27	111	17	4	1	12	10	23
Total	6,900	708	128	23	572	477	1,400

4.3.7. Summary: Contribution from All Sources

Based on the inventory of sources discussed in this chapter, a summary of the contribution by the different nonpoint sources to direct annual fecal coliform loading to the streams is given in Table 4.41. Distribution of annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Table 4.41.

From Table 4.41, it is clear that nonpoint source loadings to the land surface are 250 times larger than direct loadings to the streams (not including commercial sources), with pastures receiving about 95% of the total fecal coliform load. It is premature to assume that most of the fecal coliform loading in streams originates from upland sources, primarily from pastures. Other factors such as precipitation amount and pattern, size of runoff events, manure application activities (time and method), type of waste (solid versus liquid

manure), and proximity to streams also impact the amount of fecal coliform from upland areas that reaches the streams. The HSPF model considers these factors when estimating fecal coliform loads to the receiving waters, as described in Chapter 5.

Table 4.41. Annual fecal coliform loadings to the stream and the various land use categories in the North Fork Shenandoah River watershed.

Source	Fecal coliform loading ($\times 10^{12}$ cfu/year)	Percent of total loading
Direct loading to streams		
Cattle in stream	346	<1%
Wildlife in stream	305	<1%
Straight pipes	125	<1%
Loading to land surfaces		
Cropland	2,439	1%
Pasture	192,448	95%
Residential ^a	5,753	3%
Forest	1,320	1%
Total	202,737	

^a Includes loads received from both High and Low Density Residential due to failed septic systems and pets.

CHAPTER 5: MODELING PROCESS FOR BACTERIA TMDL DEVELOPMENT

A key component in developing a TMDL is establishing the relationship between pollutant loadings (both point and nonpoint) and in-stream water quality conditions. Once this relationship is developed, management options for reducing pollutant loadings to streams can be assessed. In developing a TMDL, it is critical to understand the processes that affect the fate and transport of the pollutants and cause the impairment of the waterbody of concern. Pollutant transport to water bodies is evaluated using a variety of tools, including monitoring, geographic information systems (GIS), and computer simulation models. In this chapter, the modeling process, input data requirements, and model calibration procedure and results are discussed.

5.1. Model Description

The TMDL development requires the use of a watershed-based model that integrates both point and nonpoint sources and simulates in-stream water quality processes. The Hydrologic Simulation Program – FORTRAN (HSPF) version 12 (Bicknell *et al.*, 2001; Duda *et al.*, 2001) was used to model fecal coliform transport and fate in the watersheds. The ArcGIS 9.1 GIS program was used to display and analyze landscape information for the development of input for HSPF.

The HSPF model simulates nonpoint source runoff and pollutant loadings, performs flow routing through streams, and simulates in-stream water quality processes. HSPF estimates runoff from both pervious and impervious parts of the watershed and stream flow in the channel network. The sub-module PWATER within the module PERLND simulates runoff, and hence, estimates the water budget on pervious areas (e.g., agricultural land). Runoff from impervious areas is modeled using the IWATER sub-module within the IMPLND module. The simulation of flow through the stream network is performed using the sub-modules HYDR and ADCALC within the module RCHRES. While HYDR routes

the water through the stream network, ADCALC calculates variables used for simulating convective transport of the pollutant in the stream. Fate of fecal coliform on pervious and impervious land segments is simulated using the PQUAL (PERLND module) and IQUAL (IMPLND module) sub-modules, respectively. Fate of fecal coliform in stream water is simulated using the general constituent pollutant (GQUAL) sub-module within RCHRES module. Fecal coliform bacteria are simulated as dissolved pollutants in the GQUAL sub-module.

5.2. Input Data Requirements

The HSPF model requires a wide variety of input data to describe hydrology, water quality, and land use characteristics of the watershed. The different types and sources of input data used to develop the TMDLs for the North Fork Shenandoah River watershed are discussed below.

5.2.1. Climatological Data

Hourly precipitation data were obtained from the Dale Enterprise weather station in Rockingham County, located right outside the southern part of the watershed. Because hourly data for other meteorological parameters were not available at Dale Enterprise, daily data from Mathias and Star Tannery (Virginia) were used to complete and update the meteorological data set required for running HSPF. Detailed descriptions of the weather data and the procedure for converting the raw data into the required data set are presented in Appendix D.

5.2.2. Model Parameters

The hydrology parameters required by HSPF were defined for every land use category for each sub-watershed. Required hydrology parameters are listed in the HSPF Version 12 User's Manual (Bicknell *et al.*, 2001). Initial estimates for required hydrology parameters were generated based on guidance in BASINS Technical Note 6 (USEPA, 2000a); these parameters were refined during calibration. Each reach requires a function table (FTABLE) to describe the relationship between water depth, surface area, volume, and discharge (Bicknell

et al., 2001). The FTABLE parameters were estimated using a digital elevation model (DEM) of the area in addition to relationships developed by the NRCS that relate stream characteristics to drainage area. Information on the calculated stream geometry for the bankfull condition of each sub-watershed is presented in Table 5.1 for the Upper Watershed, Table 5.2 for the Lower Watershed, Table 5.3 for Stony Creek, and Table 5.4 for Mill Creek.

Required water quality parameters are also given in the HSPF User's Manual (Bicknell *et al.*, 2001). Initial estimates for bacteria loading parameters were based on estimates of bacteria production in the watershed; estimates of die-off rates and subsurface bacteria concentrations were based on values commonly used in previous TMDLs.

Table 5.1. Stream Characteristics of the Upper North Fork Shenandoah Watershed.

Sub-watershed	Length	Average bankfull width (ft)	Average bankfull channel depth (ft)	Slope (ft/ft)
1	1.31	101.3	7.80	0.0028
2	0.88	101.0	7.78	0.0042
3	2.54	46.0	4.12	0.0061
4	4.05	26.9	2.68	0.0221
5	7.03	37.8	3.52	0.0109
6	5.25	52.9	4.61	0.0062
7	4.90	37.6	3.50	0.0162
8	7.26	32.8	3.14	0.0395
9	3.30	88.5	6.99	0.0034
10	4.37	50.0	4.40	0.0108
11	6.56	31.7	3.05	0.0561
12	0.86	38.5	3.57	0.0159
13	5.40	37.9	3.53	0.0503
14	3.55	79.2	6.39	0.0052
15	3.12	73.6	6.02	0.0052
16	6.72	38.4	3.56	0.0198
17	2.51	66.4	5.54	0.0047
18	6.55	48.3	4.28	0.0234
19	6.26	49.8	4.39	0.0110
20	7.86	41.1	3.76	0.0385

Table 5.2. Stream Characteristics of the Lower North Fork Shenandoah Watershed.

Sub-watershed	Length	Average bankfull width (ft)	Average bankfull channel depth (ft)	Slope (ft/ft)
1	3.83	104.7	8.01	0.0013
2	5.32	37.3	3.48	0.0305
3	10.94	100.5	7.75	0.0011
4	7.14	39.0	3.60	0.0101
5	12.03	95.1	7.41	0.0011
6	5.86	36.9	3.44	0.0138
7	3.97	90.4	7.11	0.0011
8	6.35	31.7	3.05	0.0091
9	11.94	87.7	6.94	0.0008
10	10.73	42.5	3.86	0.0173
11	4.73	80.5	6.47	0.0012
12	10.61	78.9	6.37	0.0016
13	0.33	71.0	5.85	0.0056
14	1.07	71.0	5.85	0.0006
15	3.49	70.7	5.83	0.0012
16	5.55	69.0	5.72	0.0020
17	3.48	65.8	5.50	0.0021
18	8.54	38.5	3.57	0.0048
19	2.79	53.8	4.67	0.0007
20	4.07	25.5	2.56	0.0198
21	1.82	44.5	4.01	0.0024
22	1.46	43.6	3.94	0.0013
23	3.47	21.5	2.24	0.0216
24	1.40	38.5	3.57	0.0018
25	2.71	18.4	1.97	0.0245
26	4.06	32.1	3.08	0.0204
27	0.65	16.0	1.77	0.0066

Table 5.3. Stream Characteristics of the Stony Creek Watershed.

Sub-watershed	Length	Average bankfull width (ft)	Average bankfull channel depth (ft)	Slope (ft/ft)
28	0.68	80.6	6.48	0.0018
29	4.20	24.5	2.49	0.0067
30	0.55	79.3	6.40	0.0080
31	1.36	79.0	6.38	0.0023
32	6.77	28.9	2.84	0.0056
33	0.61	76.7	6.23	0.0010
34	6.69	32.1	3.08	0.0084
35	0.58	73.8	6.03	0.0043
36	0.21	70.1	5.79	0.0176
37	7.13	27.2	2.70	0.0099
38	1.76	71.7	5.90	0.0039
39	0.98	70.9	5.84	0.0032
40	3.32	69.9	5.78	0.0049
41	6.69	33.3	3.18	0.0551
42	3.60	62.3	5.26	0.0047
43	7.37	30.5	2.96	0.0099
44	0.11	56.5	4.86	0.0055
45	0.38	56.5	4.86	0.0008
46	5.12	28.2	2.78	0.0318
47	1.90	52.9	4.61	0.0039
48	2.94	25.5	2.57	0.0239
49	0.97	48.9	4.33	0.0013
50	2.93	26.8	2.67	0.0203
51	2.64	44.6	4.02	0.0045
52	2.26	20.9	2.19	0.0314
53	1.66	40.2	3.69	0.0041
54	3.45	24.6	2.49	0.0370
55	5.16	34.1	3.24	0.0154

Table 5.4. Stream Characteristics of the Mill Creek Watershed.

Sub-watershed	Length	Average bankfull width (ft)	Average bankfull channel depth (ft)	Slope (ft/ft)
56	1.04	57.9	4.96	0.0102
57	1.10	56.8	4.88	0.0034
58	0.68	54.8	4.74	0.0073
59	3.89	27.9	2.76	0.0101
60	2.68	50.6	4.45	0.0044
61	2.13	45.1	4.05	0.0064
62	4.60	28.9	2.83	0.0173
63	3.50	34.2	3.24	0.0064
64	3.90	24.6	2.49	0.0258

5.3. Accounting for Pollutant Sources

5.3.1. Overview

There were 2 VPDES facilities permitted to discharge bacteria into the Upper Watershed and 17 general permit dischargers. There were 7 VPDES facilities permitted to discharge bacteria into Lower Watershed and 57 general permit dischargers. There were 4 existing VPDES facilities permitted to discharge bacteria into Stony Creek and 26 general permit discharges. There were 12 general permit discharges into Mill Creek. (Table 4.1). The fecal coliform concentration in the discharges from these facilities cannot exceed 200 cfu/100 mL. During calibration, reported concentrations from these facilities were incorporated into the model; during allocation, concentrations from these facilities were set at their permitted limits. Other permitted facilities existing in the areas covered by a previously developed TMDL are summarized in previous TMDL reports and were included as part of the input to the North Fork from those areas with previous TMDLs. The simulated output from the watersheds with previous TMDL plans was used as inflow to North Fork Shenandoah River. For the existing conditions, the simulated flow and bacteria loads for the existing conditions of watersheds with previous TMDL plans were used. For the TMDL

allocation, the simulated flow and a continuous concentration of 126 cfu/100 mL were used for the inflows to North Fork Shenandoah River.

Bacteria loads that are directly deposited by cattle and wildlife in streams were treated as direct nonpoint sources in the model. Bacteria that were land-applied or deposited on land were treated as nonpoint source loadings; all or part of that load may be transported to the stream as a result of surface runoff during rainfall events. Direct nonpoint source loading was applied to the stream reach in each sub-watershed as appropriate. The point sources permitted to discharge bacteria in the watershed were incorporated into the simulations at the stream locations designated in the permit.

The nonpoint source loading was applied in the form of fecal coliform counts to each land use category in a sub-watershed. Fecal coliform die-off was simulated while manure was being stored, while it was on the land, and while it was transported in streams. Both direct nonpoint and nonpoint source loadings were varied by month to account for seasonal differences such as cattle and wildlife access to streams.

We developed a spreadsheet program internally (Zeckoski et al., 2005) and used it to generate the nonpoint source fecal coliform inputs to the HSPF model. This spreadsheet program takes inputs of animal numbers, land use, and management practices by sub-watershed and outputs hourly direct deposition to streams and monthly loads to each land use type. We customized the program to allow direct deposition in the stream by dairy cows, ducks, and geese to occur only during daylight hours. The spreadsheet program calculates the manure produced in confinement by each animal type (dairy cows, beef cattle, and poultry) and distributes this manure to available lands (crops and pasture) within each sub-watershed. If a sub-watershed does not have sufficient land to apply all the manure its animals generate, the excess manure is distributed equally to other sub-watersheds that have land that has not yet received manure.

5.3.2. Modeling fecal coliform die-off

Fecal coliform die-off was modeled using first order die-off of the form:

$$C_t = C_0 10^{-Kt} \quad [5.1]$$

where: C_t = concentration or load at time t ,

C_0 = starting concentration or load,

K = decay rate (day^{-1}),

and t = time in days.

A review of literature provided estimates of decay rates that could be applied to waste storage and handling in the North Fork Shenandoah River, Stony Creek, and Mill Creek watersheds (Table 5.5).

Table 5.5. First order decay rates for different animal waste storage as affected by storage/application conditions and their sources.

Waste type	Storage/application	Decay rate (day^{-1})	Reference
Dairy manure	Pile (not covered)	0.066	Crane and Moore (1986)
	Pile (covered)	0.028	
Beef manure	Anaerobic lagoon	0.375	Crane and Moore (1986)
Poultry litter	Soil surface	0.035	Giddens <i>et al.</i> (1973)
		0.342	Crane <i>et al.</i> (1980)

Based on the values cited in the literature, the following decay rates were used in simulating fecal coliform die-off in stored waste.

- Liquid dairy manure: Because the decay rate for liquid dairy manure storage could not be found in the literature, the decay rate for beef manure in anaerobic lagoons (0.375 day^{-1}) was used.
- Solid cattle manure: Based on the range of decay rates ($0.028\text{--}0.066 \text{ day}^{-1}$) reported for solid dairy manure, a decay rate of 0.05 day^{-1} was used, assuming that a majority of manure piles are not covered.
- Poultry waste in pile/house: Because no decay rates were found for poultry waste in storage, a decay rate of 0.035 day^{-1} was used based on the lower decay rate reported for poultry litter applied to the soil surface. The lower value was used instead of the higher

value of 0.342 day^{-1} (Table 5.5) because fecal coliform die-off in storage was assumed to be lower, given the absence of UV radiation and predation by soil microbes.

The procedure for calculating fecal coliform counts in waste at the time of land application is included in Appendix C. Depending on the duration of storage, type of storage, type of manure, and die-off factor, the fraction of fecal coliform surviving in the manure at the end of storage is calculated. While calculating survival fraction at the end of the storage period, the daily addition of manure and coliform die-off of each fresh manure addition is considered to arrive at an effective survival fraction over the entire storage period. The amount of fecal coliform available for application to land per year is estimated by multiplying the survival fraction with total fecal coliform produced per year (in as-excreted manure). Monthly fecal coliform application to land is estimated by multiplying the amount of fecal coliform available for application to land per year by the fraction of manure applied to land during that month. A base-10 decay rate of 0.05 day^{-1} was assumed for fecal coliform on the land surface. The decay rate of 0.05 day^{-1} is represented in HSPF by specifying a maximum surface buildup of nine times the daily loading rate. An in-stream decay rate of 1.15 day^{-1} was used.

5.3.3. Modeling Nonpoint Sources

For modeling purposes, nonpoint fecal coliform loads were those that were deposited or applied to land and, hence, required surface runoff events for transport to streams. Fecal coliform loading by land use for all sources in each sub-watershed is presented in Chapter 4. The existing condition fecal coliform loads are based on best estimates of existing wildlife, livestock, and human populations and fecal coliform production rates. Fecal coliform in stored waste was adjusted for die-off prior to the time of land application when calculating loadings to cropland and pasture. For a given period of storage, the total amount of fecal coliform present in the stored manure was adjusted for die-off on a daily basis. Fecal coliform loadings to each sub-watershed in the North Fork

Shenandoah River TMDL watershed are presented in Appendix F, Stony Creek fecal coliform loadings are presented in Appendix G, and Mill Creek fecal coliform loadings are presented in Appendix H. The sources of fecal coliform to different land use categories and how the model handled them are briefly discussed below.

1. Cropland: Liquid dairy manure and solid manure are applied to cropland as described in Chapter 4. Fecal coliform loadings to cropland were adjusted to account for die-off during storage and partial incorporation during land application. Wildlife contributions were also added to the cropland areas. For modeling, the monthly fecal coliform loading assigned to cropland was distributed over the entire cropland acreage within a sub-watershed. Thus, loading rate varied by month and sub-watershed.
2. Pasture: In addition to direct deposition from livestock and wildlife, pastures receive applications of liquid dairy manure and solid manure as described in Chapter 4. Applied fecal coliform loading to pasture was reduced to account for die-off during storage. For modeling, the monthly fecal coliform loading assigned to pasture was distributed over the entire pasture acreage within a sub-watershed.
3. Low Density Residential: Fecal coliform loading on rural residential land use came from failing septic systems and waste from pets. In the model simulations, fecal coliform loads produced by failing septic systems and pets in a sub-watershed were combined and assumed to be uniformly applied to the low density residential pervious land use areas. Impervious areas (Table 3.3) received constant loads of 1.0×10^7 cfu/acre/day.
4. High-Density Residential: Fecal coliform loading to the high density residential land use came from pets in these areas; the impervious load was assumed to be a constant 1.0×10^7 cfu/acre/day (USEPA, 2000b).
5. Forest: Wildlife not defecating in streams, cropland, or pastures provided fecal coliform loading to the forested land use. Fecal coliform from wildlife

in forests was applied uniformly over the forest areas in each sub-watershed.

5.3.4. Modeling Direct Nonpoint Sources

Fecal coliform loads from direct nonpoint sources included cattle in streams, wildlife in streams, and direct loading to streams from straight pipes from residences. Loads from direct nonpoint sources in each sub-watershed are described in detail in Chapter 4. Contributions of fecal coliform from interflow and groundwater were modeled as having a constant concentration of 30 cfu/100mL for interflow and 20 cfu/100mL for groundwater.

5.4. Model Calibration and Validation

Model calibration is the process of selecting model parameters that provide an accurate representation of the watershed. In this section, the procedures followed for calibrating the hydrology and water quality components of the Hydrological Simulation Program-FORTRAN (HSPF) model are discussed.

5.4.1. Hydrology

The HSPEXP decision support system developed by USGS was used to assist in calibrating the hydrologic portion of HSPF for North Fork Shenandoah River, Stony Creek, and Mill Creek. The default HSPEXP criteria for evaluating the accuracy of the flow simulation were used in the calibration for all three watersheds. These criteria are listed in Table 5.6. After calibration, all criteria listed in Table 5.6 were met.

Table 5.6. Default criteria for HSPEXP.

Variable	Percent Error
Total Volume	10%
50 % Lowest Flows	10%
10 % Highest Flows	15%
Storm Peaks	15%
Seasonal Volume Error	10%
Summer Storm Volume Error	15%

1.4.1.a. North Fork Shenandoah

The North Fork Shenandoah Watershed was divided into 20 sub-watersheds upstream of the impaired segment (Upper Watershed) and 20 sub-watersheds incorporating the impairment and downstream reaches (Lower Watershed). The hydrologic calibration period for the Upper Watershed was September 1, 1986 to August 31, 1991. The hydrologic validation period for the Upper Watershed was from September 1, 1991 to August 31, 1995. The hydrologic calibration period for the Lower Watershed was September 1, 1988 to August 31, 1993. The hydrologic validation period for the Lower Watershed was from September 1, 1996 to August 31, 1998. The output from the HSPF model for both calibration and validation was daily average flow in cubic feet per second (cfs). Calibration parameters were adjusted within the recommended range (USEPA, 2000a).

The simulated flow for both the calibration and validation of the Upper Watershed matched the observed flow well, as shown in Figure 5.1 and Figure 5.2. The agreement with observed flows is further illustrated in Figure 5.3 and Figure 5.4 for a representative year and Figure 5.5 and Figure 5.6 for a representative storm. The agreement between the simulated and observed time series can be further seen through the comparison of their cumulative frequency curves (Figure 5.7 and Figure 5.8).

The simulated flow for both the calibration and validation of the Lower Watershed matched the observed flow well, as shown in Figure 5.9 and Figure 5.10. The agreement with observed flows is further illustrated in Figure 5.11 and Figure 5.12 for a representative year and Figure 5.13 and Figure 5.14 for a representative storm. The agreement between the simulated and observed time series can be further seen through the comparison of their cumulative frequency curves (Figure 5.15 and Figure 5.16).

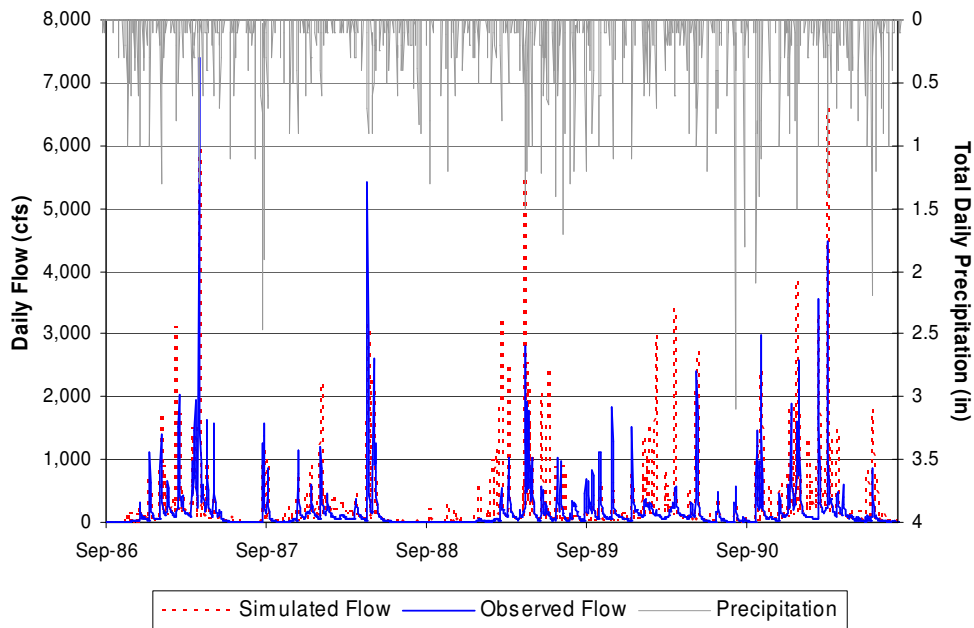


Figure 5.1. Observed and simulated flows and precipitation for the Upper Watershed for the calibration period.

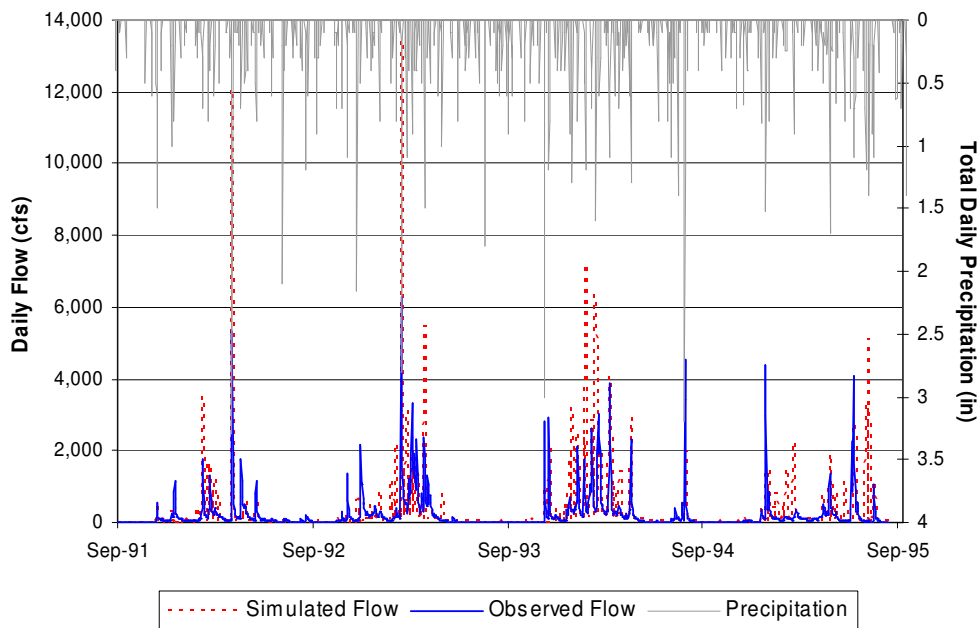


Figure 5.2. Observed and simulated flows and precipitation for the Upper Watershed during the validation period.

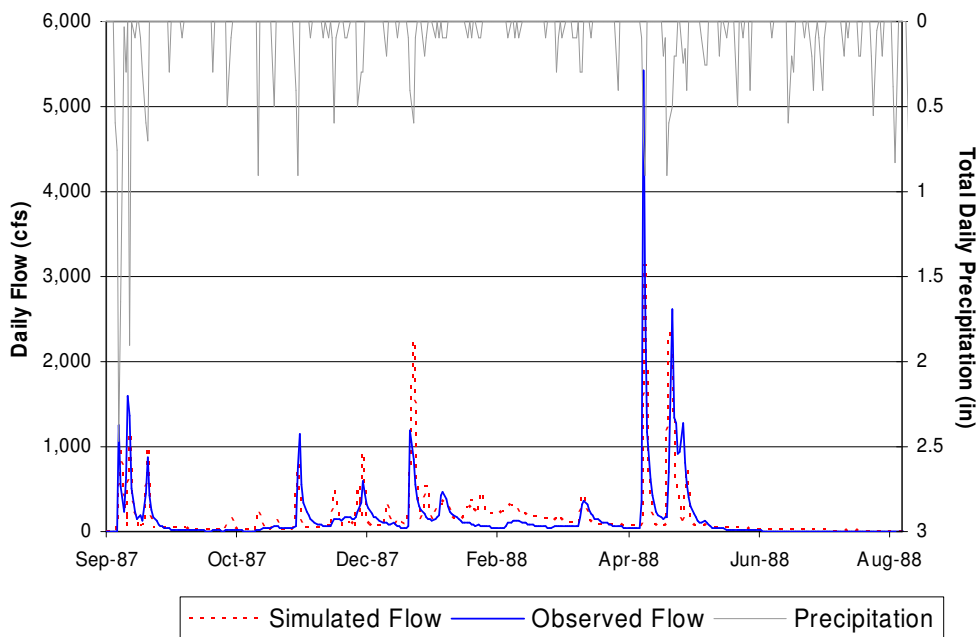


Figure 5.3. Observed and simulated flows and precipitation for Upper Watershed for a representative year in the calibration period.

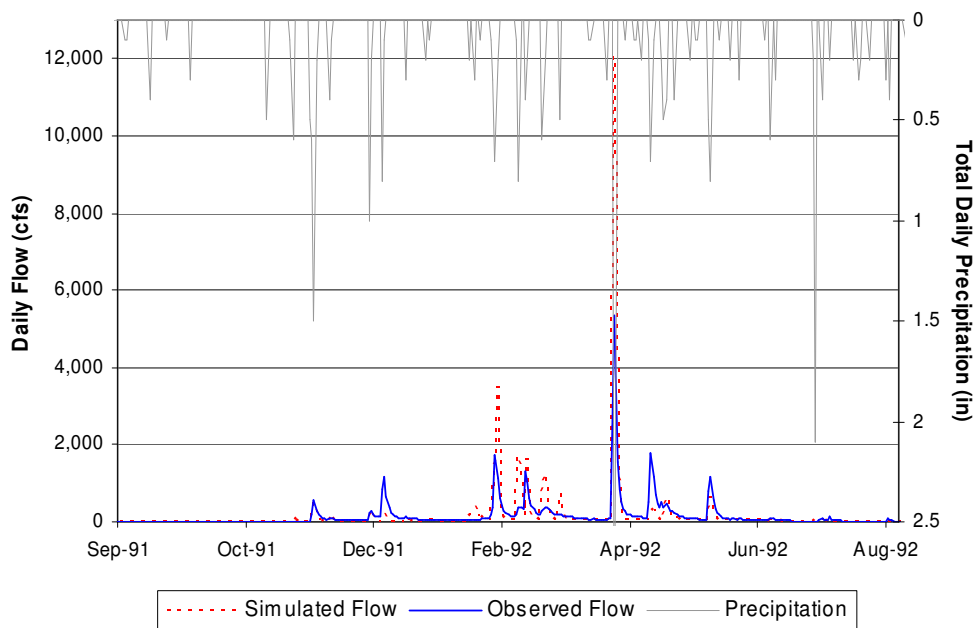


Figure 5.4. Observed and simulated flows and precipitation for Upper Watershed during a representative year in the validation period.

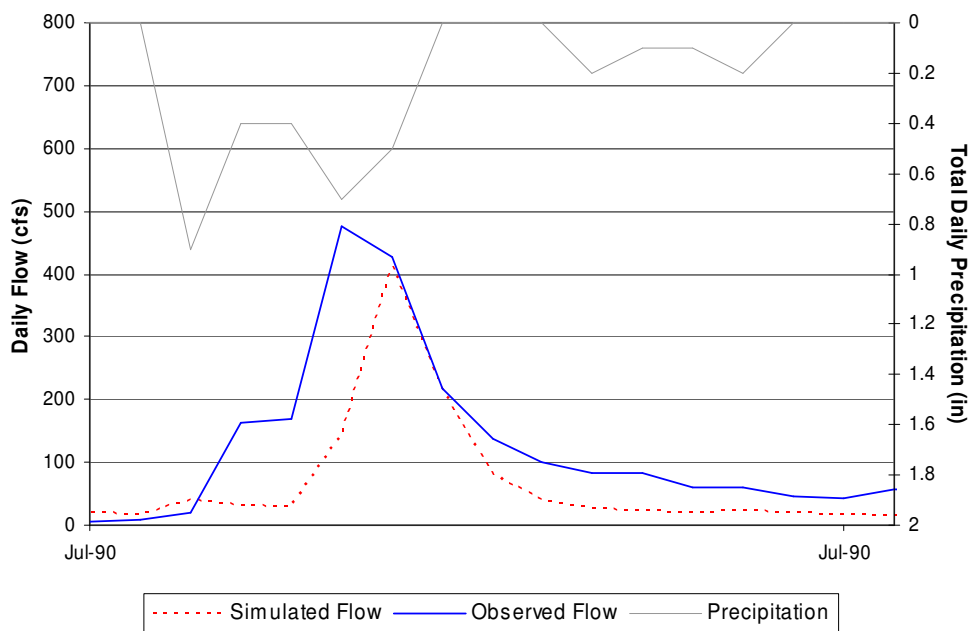


Figure 5.5. Observed and simulated flows and precipitation for the Upper Watershed for a representative storm in the calibration period.

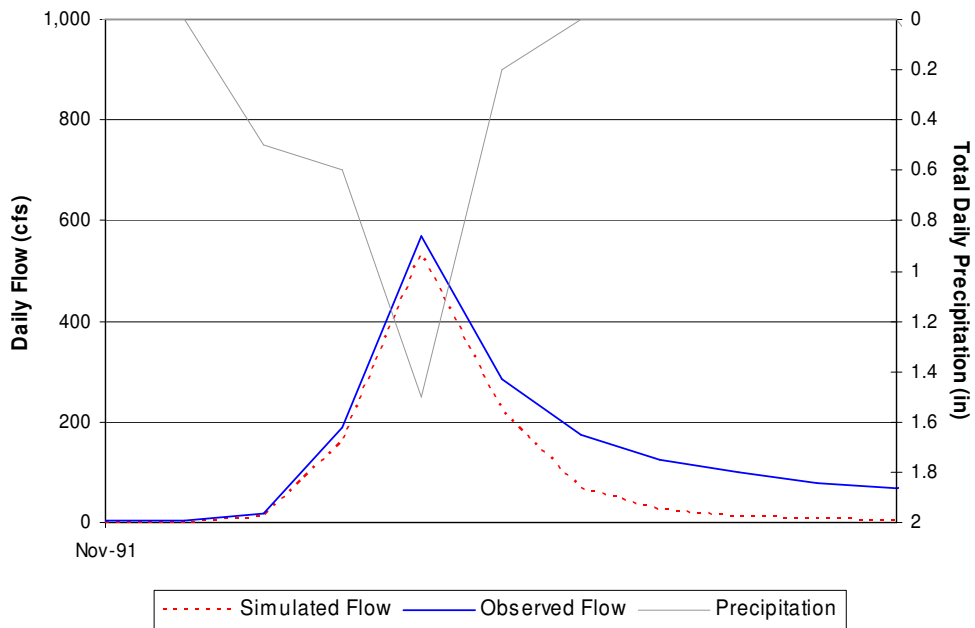


Figure 5.6. Observed and simulated flows and precipitation for the Upper Watershed for a representative storm in the validation period.

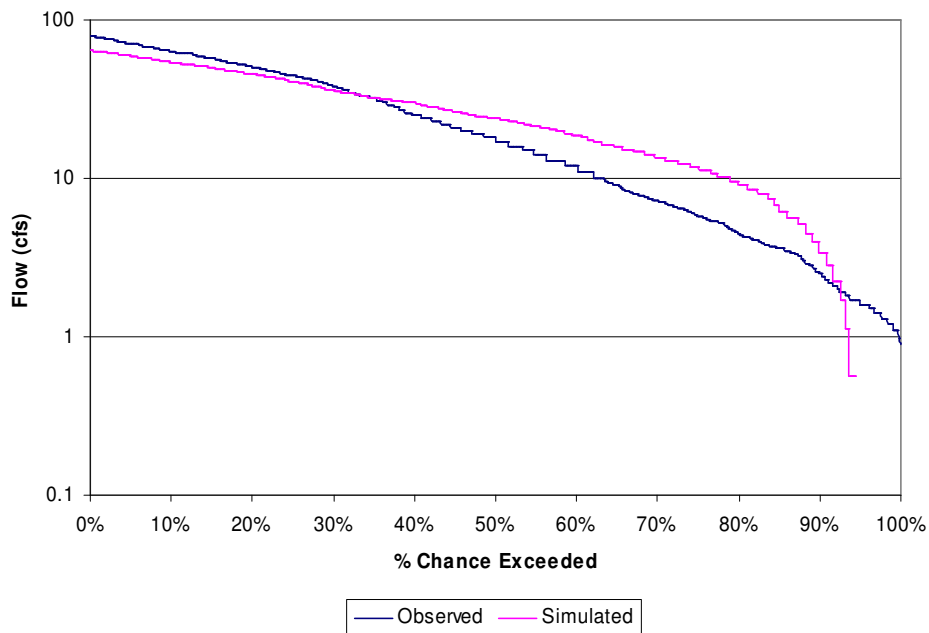


Figure 5.7. Cumulative frequency curves for the calibration period for the Upper Watershed.

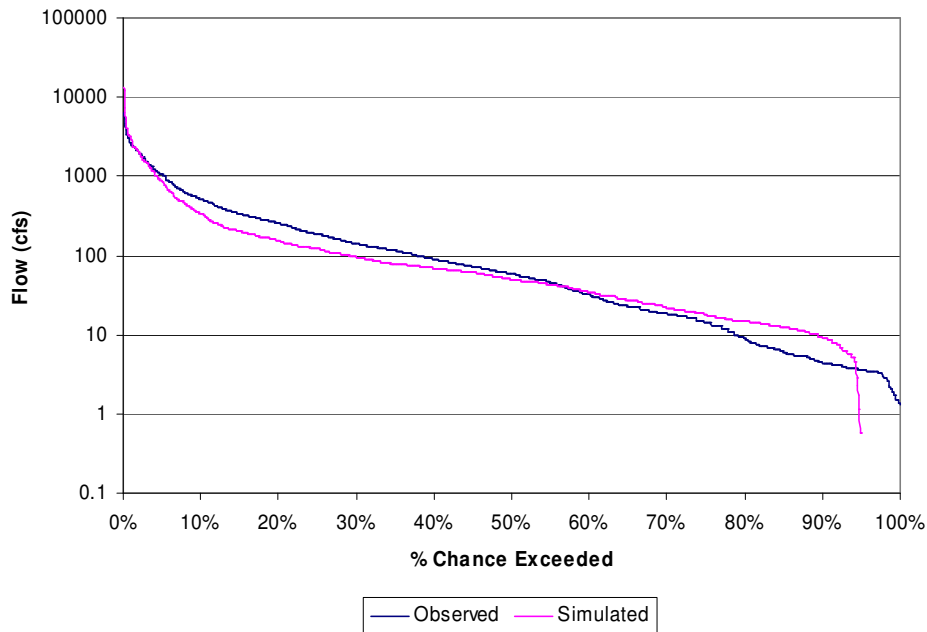


Figure 5.8. Cumulative frequency curves for the validation period for the Upper Watershed.

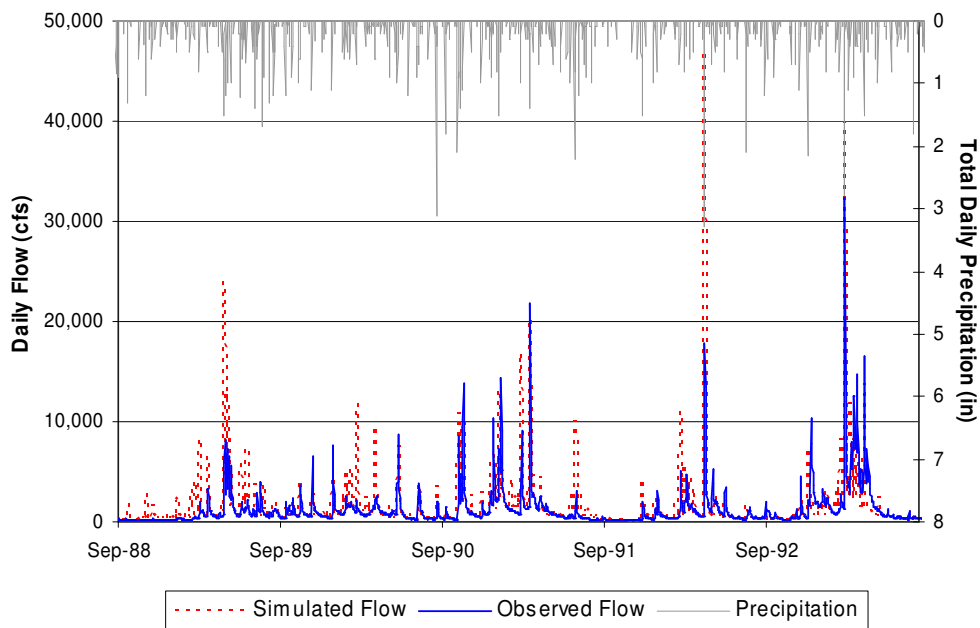


Figure 5.9. Observed and simulated flows and precipitation for the Lower Watershed for the calibration period.

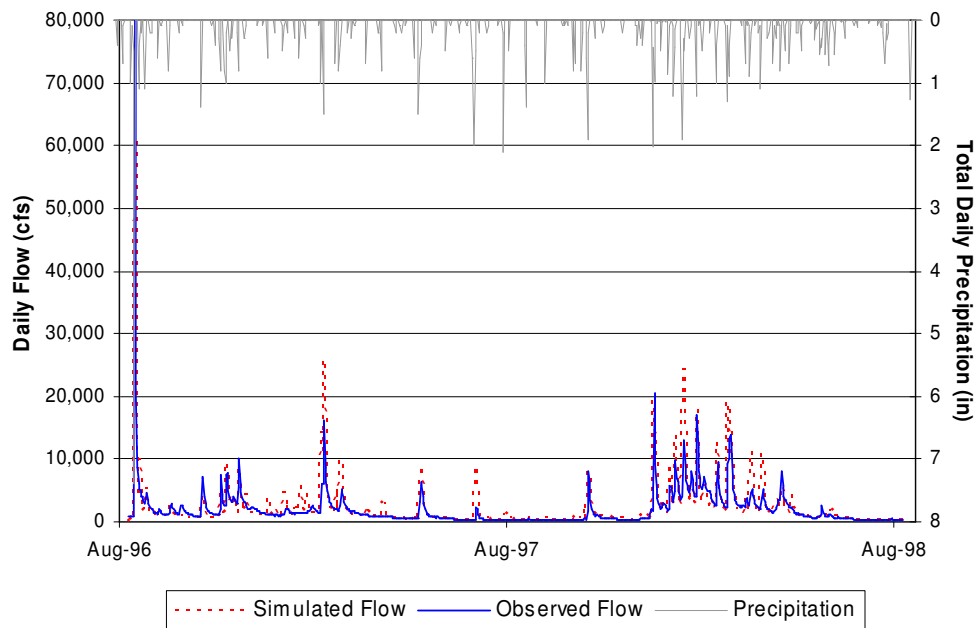


Figure 5.10. Observed and simulated flows and precipitation for the Lower Watershed during the validation period.

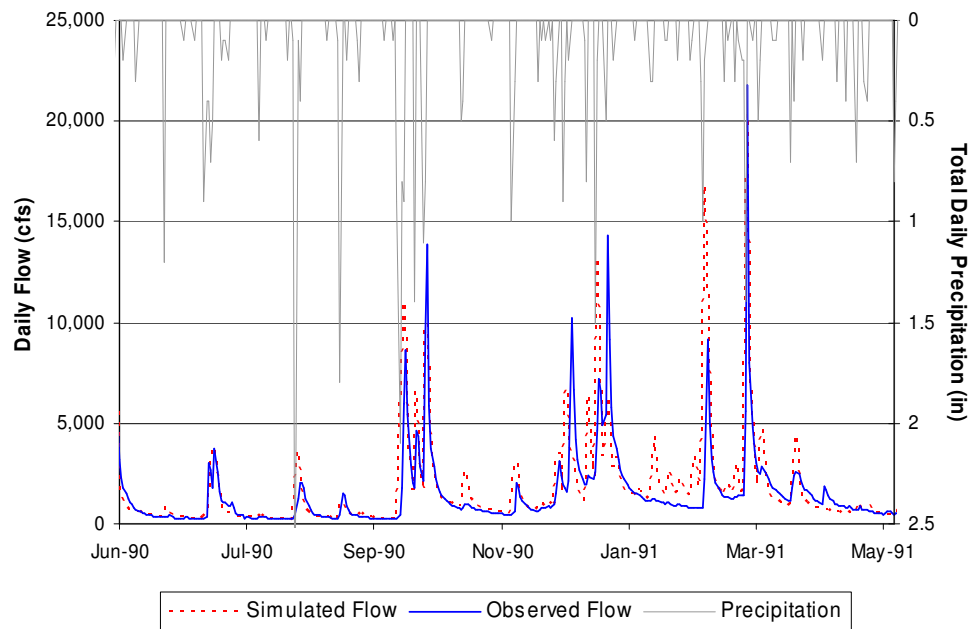


Figure 5.11. Observed and simulated flows and precipitation for Lower Watershed for a representative year in the calibration period.

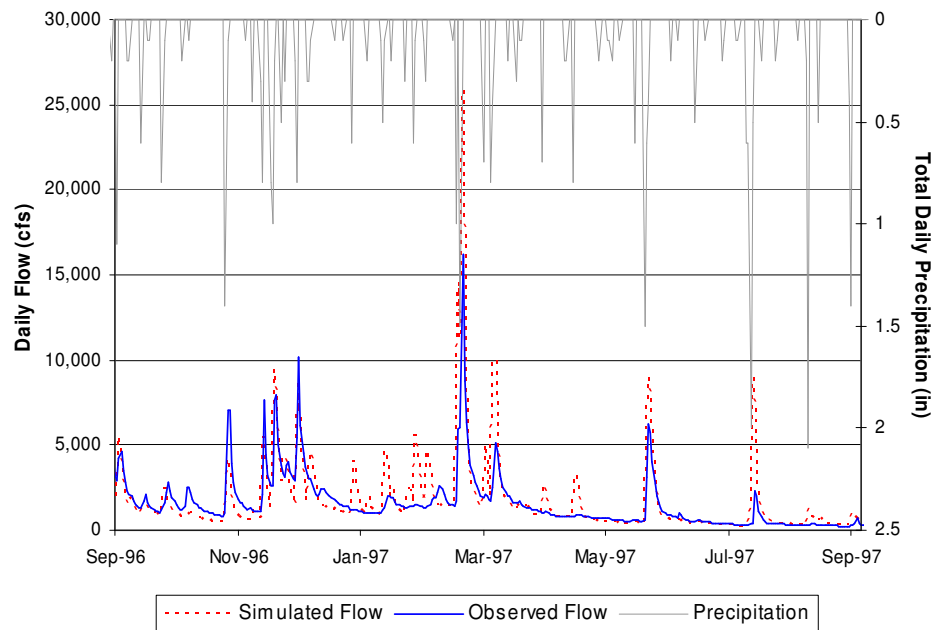


Figure 5.12. Observed and simulated flows and precipitation for the Lower Watershed during a representative year in the validation period.

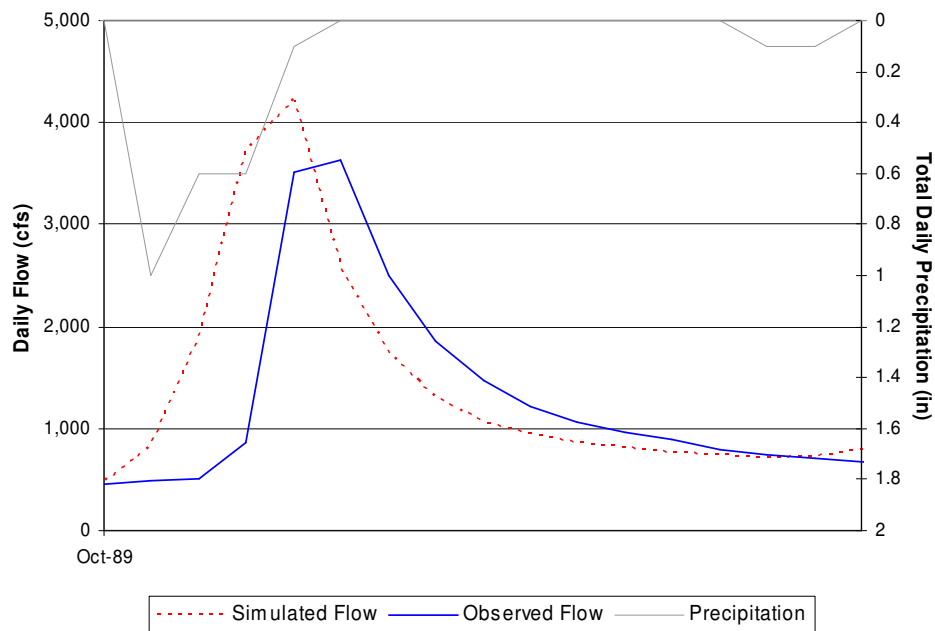


Figure 5.13. Observed and simulated flows and precipitation for the Lower Watershed for a representative storm in the calibration period.

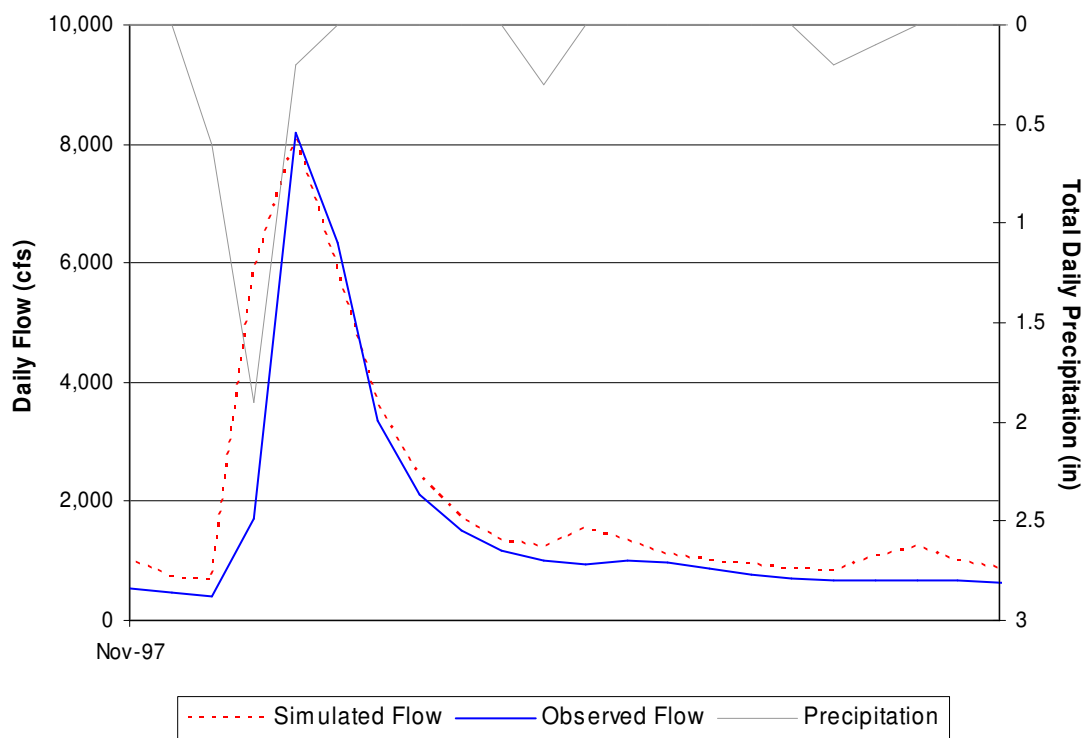


Figure 5.14. Observed and simulated flows and precipitation for the Lower Watershed for a representative storm in the validation period.

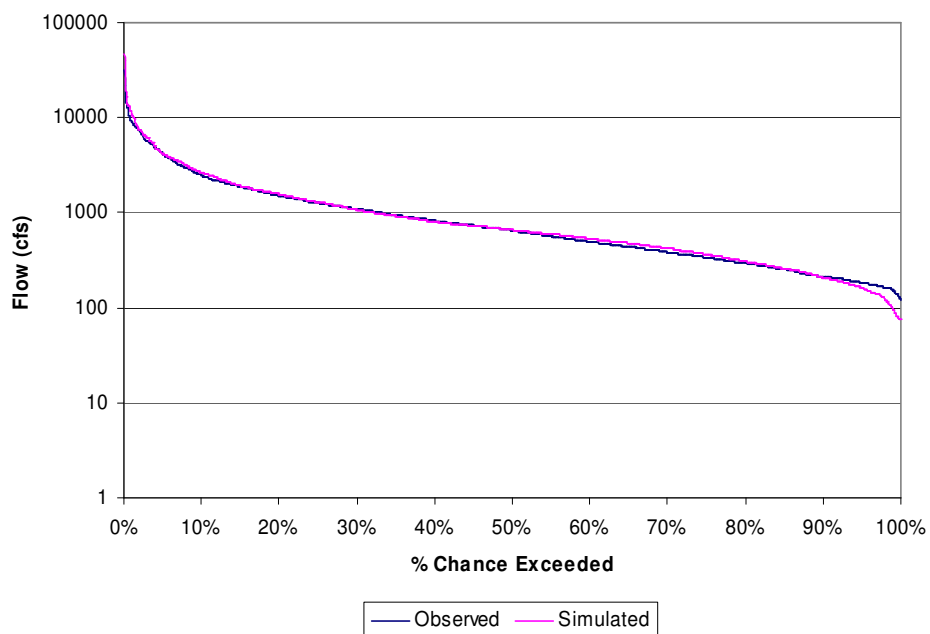


Figure 5.15. Cumulative frequency curves for the calibration period for the Lower Watershed.

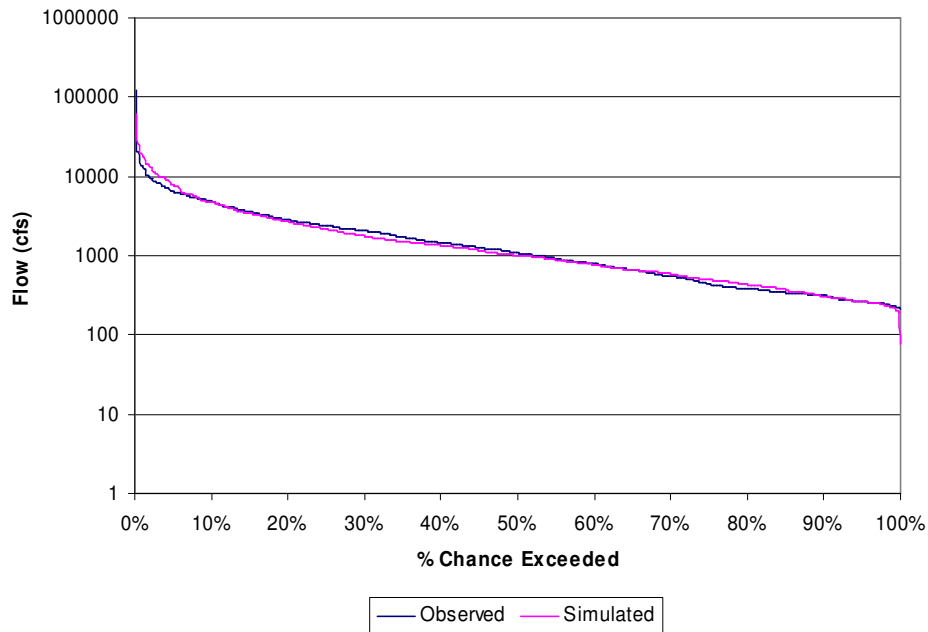


Figure 5.16. Cumulative frequency curves for the validation period for the Lower Watershed.

Selected diagnostic output from the program is listed in Table 5.7 and Table 5.8 for the upper watershed and Table 5.9 and Table 5.10 for the lower watershed. The calibration met all the acceptance criteria in both the calibration period and the validation period. This indicates that the developed hydrologic model produces an acceptable prediction of the flows in the North Fork of the Shenandoah River.

Table 5.7. Summary statistics for the calibration period for the Upper Watershed.

Category	Error (%)	Criterion
Total Runoff	-3.4	10%
Average Annual Total Runoff	0	10%
Total of Highest 10% of flows	+7.1	15%
Total of Lowest 50% of flows	+3.2	10%

Table 5.8. Summary statistics for the validation period for the Upper Watershed.

Category	Error (%)	Criterion
Total Runoff	-8.7	10%
Average Annual Total Runoff	0	10%
Total of Highest 10% of flows	+12.8	15%
Total of Lowest 50% of flows	+3.8	10%

Table 5.9. Summary statistics for the calibration period for the Lower Watershed.

Category	Error (%)	Criterion
Total Runoff	+7.3	10%
Average Annual Total Runoff	-0.01	10%
Total of Highest 10% of flows	+4.1	15%
Total of Lowest 50% of flows	+13.6	10%

Table 5.10. Summary statistics for the validation period for the Lower Watershed.

Category	Error (%)	Criterion
Total Runoff	+1.4	10%
Average Annual Total Runoff	0	10%
Total of Highest 10% of flows	+1.5	15%
Total of Lowest 50% of flows	+9.9	10%

5.4.2. Water Quality Calibration

The water quality calibration was performed at an hourly time step using the HSPF model. Four water quality monitoring stations were used in the calibration: 1BNFS093.53 (upper watershed North Fork of the Shenandoah River), 1BNFS054.75 (lower watershed North Fork of the Shenandoah River),

1BSTY001.22 (Stony Creek), and 1BMIL002.20 (Mill Creek). Each was calibrated for the period of January 1, 1991 to December 31, 2002 – this period contains all observed data available for these stations. Output from the HSPF model was generated as an hourly timeseries and daily average timeseries of fecal coliform concentration at four subwatershed outlets, corresponding to the four monitoring station locations. *E. coli* concentrations, not directly considered in the water quality calibration, but necessary for the allocation scenarios, were determined using the following translator equation supplied by DEQ:

$$\log_2 EC(cfu/100mL) = -0.0172 + 0.91905 * \log_2 FC(cfu/100mL) \quad (1)$$

The *E. coli* translator was implemented in the HSPF simulation using the GENER block. During allocation, the geometric mean will be calculated on a monthly basis.

The final calibration parameters are shown in Table 5.20. During the water quality calibration several parameters were altered. This included HSPF parameters (like FSTDEC - first order decay rate of bacteria). Flow stagnation in the streams and rivers was also accounted for by increasing the lowest volume in the reach at which flow would occur. At volumes below the lowest value, no flow from the reach would occur (stagnation) and bacteria would be held in the reach subject to die-off. The flow stagnation attempted to simulate the conditions when water is pooled in streams and not flowing. Additionally, the bacteria production rate for cattle and livestock numbers were altered from the initial estimates, but not by a large amount.

Bacterial Source Tracking information was collected at the stations BNFS081.42 (lower watershed) and BSTY001.22 (Stony Creek) for 12 months, from July 2003 to June 2004. No BST samples were collected for Mill Creek. The development of the Mill Creek TMDL plan began before BST samples could be collected. The results of this sampling are presented in Table 5.11 and Table 5.12. The

weighted average results presented are weighted based on number of isolates, overall concentration of bacteria in the sample, and flow rate.

Table 5.11. Minimum, maximum, and weighted average BST results for 12 months of samples at Station BNF081.42.

Wildlife (%)	Human (%)	Livestock (%)	Pet (%)
11%	13%	58%	17%

Table 5.12. Minimum, maximum, and weighted average BST results for 12 months of samples at Station BSTY001.22.

Wildlife (%)	Human (%)	Livestock (%)	Pet (%)
5%	2%	83%	10%

Due to the nature of the water quality modeling, the simulated contributions for each source do not correspond to the contributions observed in the BST results. The simulated contributions are for more varied conditions, such as high and low flow conditions. For the different conditions accounted for in the simulations, different sources contribute more to the breakdown of the sources. These varied conditions are difficult, if not impossible, to capture with the 12 samples collected for the BST monitoring. These considerations make direct comparison of the simulated and BST source contributions difficult. However, the data are presented for reference in the following three tables.

Table 5.13. Simulated minimum, maximum, and weighted daily average bacteria contributions for the outlet of lower watershed of the North Fork of the Shenandoah River.

Livestock (%)	Wildlife (%)	Human (%)	Pet (%)	Interflow and Groundwater (%)
34	35	20	10	1

Table 5.14. Simulated minimum, maximum, and weighted daily average bacteria contributions for the outlet of lower watershed of the Stony Creek.

Livestock (%)	Wildlife (%)	Human (%)	Pet (%)	Interflow and Groundwater (%)
30	32	30	8	<1

Table 5.15. Simulated minimum, maximum, and weighted daily average bacteria contributions for the outlet of lower watershed of the Mill Creek.

Livestock (%)	Wildlife (%)	Human (%)	Pet (%)	Interflow and Groundwater (%)
39	38	15	8	<1

The simulated fecal coliform concentrations agree well with the observed fecal coliform concentrations at all three calibration locations. Plots of the observed data with average daily simulated fecal coliform concentrations and minimum-maximum range of concentrations simulated on each day are shown for each of the watersheds in the following figures. It is important to note in these figures that the lower cap on observed values is 100 cfu/100 mL; the upper cap is 8,000 cfu/100 mL. One would not expect the observed value from a grab sample to precisely match the simulated average daily value for a particular day. However, one would expect the observed values to fall within the minimum-maximum range.

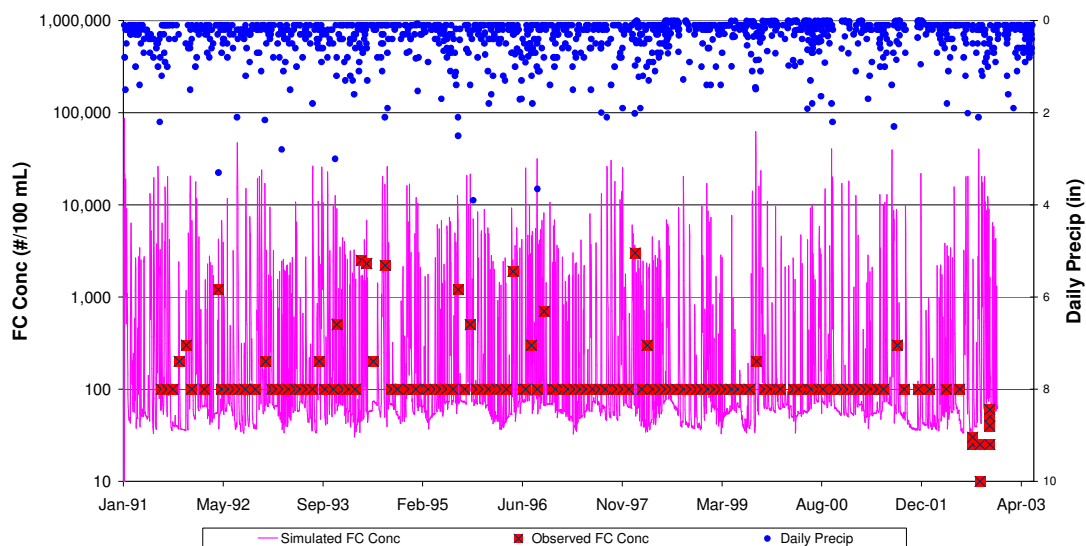


Figure 5.17. Observed and simulated fecal coliform concentrations in upper watershed of the North Fork of the Shenandoah River.

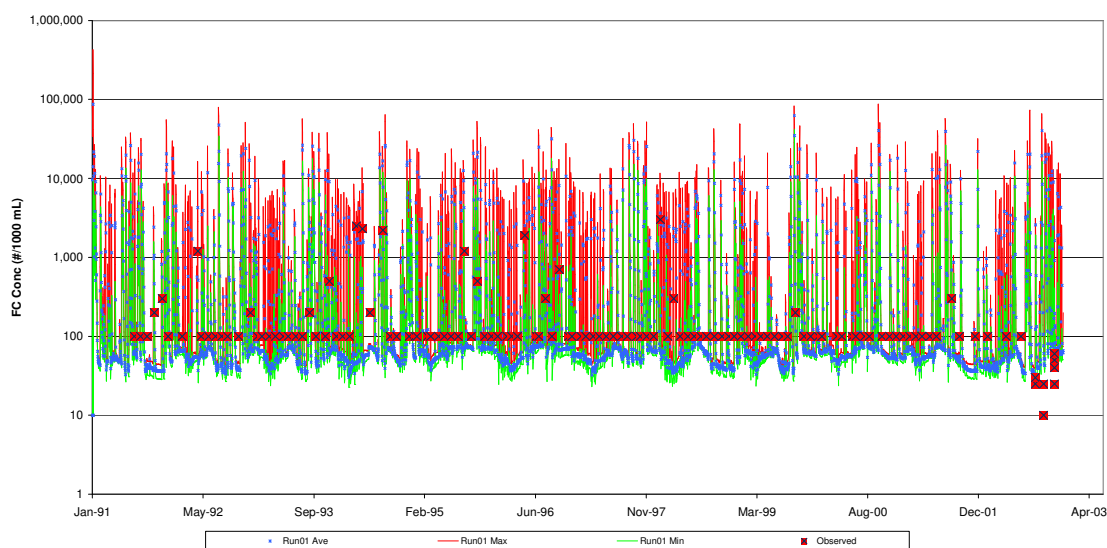


Figure 5.18. Observed fecal coliform data plotted with the daily maximum, minimum, and average simulated fecal coliform values for upper watershed of the North Fork of the Shenandoah River.

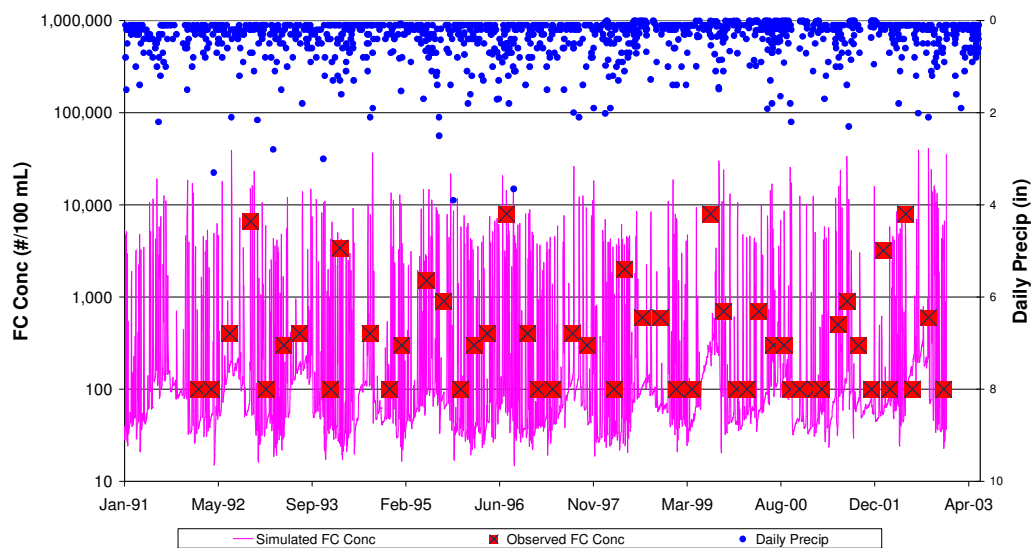


Figure 5.19. Observed and simulated fecal coliform concentrations in lower watershed of the North Fork of the Shenandoah River.

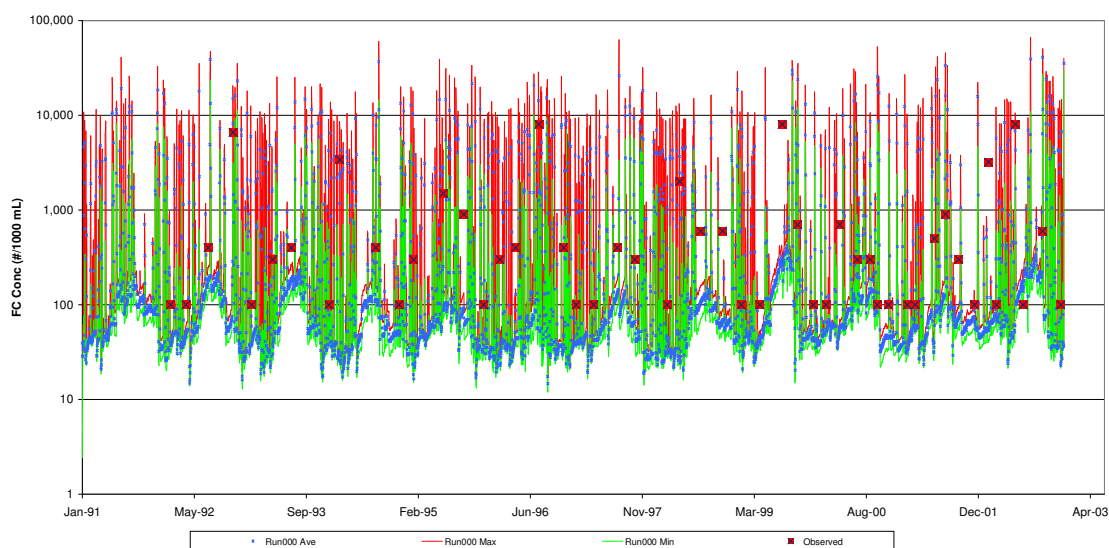


Figure 5.20. Observed fecal coliform data plotted with the daily maximum, minimum, and average simulated fecal coliform values for upper watershed of the North Fork of the Shenandoah River.

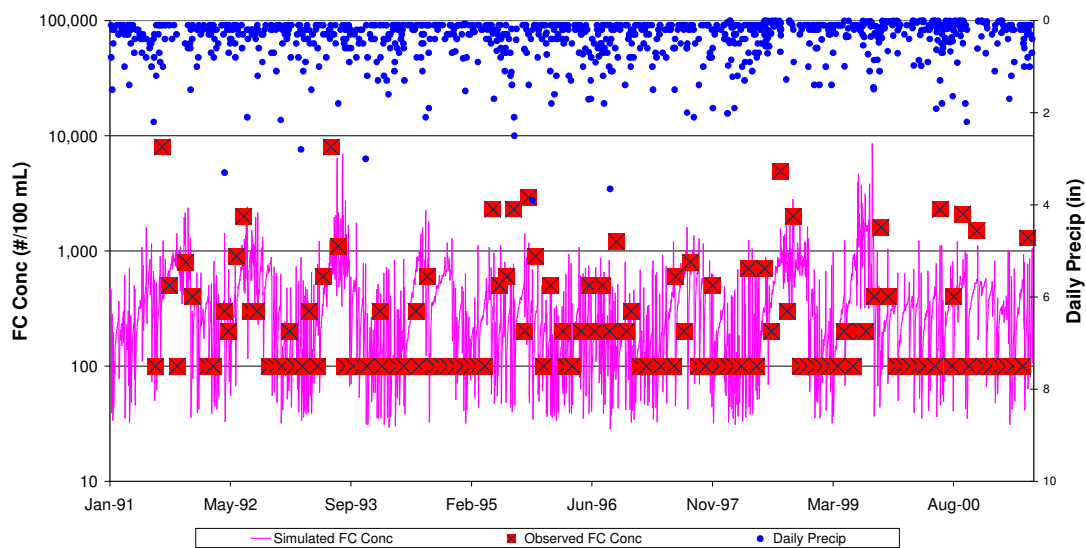


Figure 5.21. Observed and simulated fecal coliform concentrations in Stony Creek.

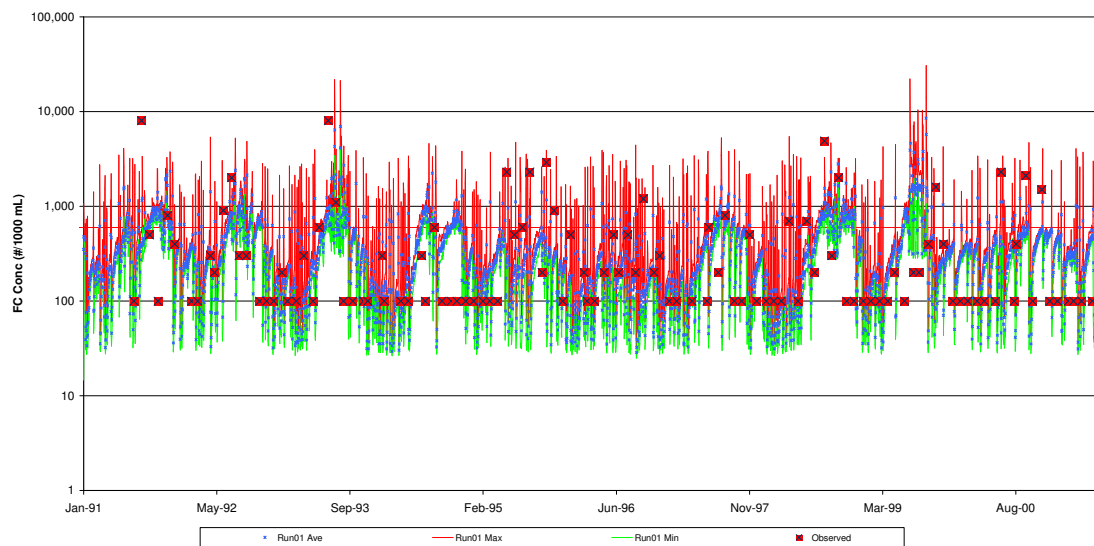


Figure 5.22. Observed fecal coliform data plotted with the daily maximum, minimum, and average simulated fecal coliform values for Stony Creek.

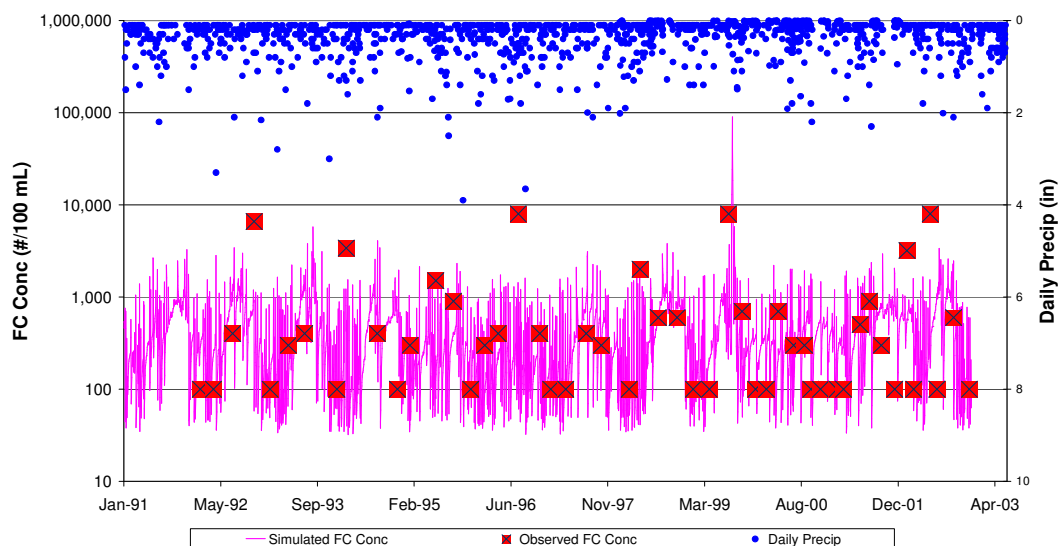


Figure 5.23. Observed and simulated fecal coliform concentrations in Mill Creek.

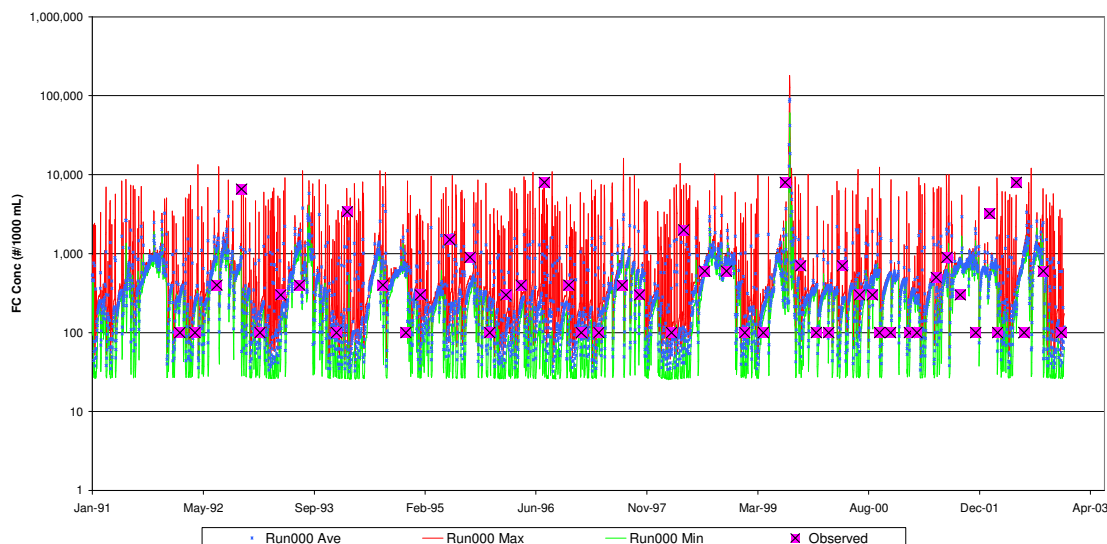


Figure 5.24. Observed fecal coliform data plotted with the daily maximum, minimum, and average simulated fecal coliform values for Mill Creek.

The observed and simulated geometric means and violation rates for all watersheds are shown in following tables. As can be seen, the simulated values closely match the observed values. Because the observed samples were collected on a monthly basis, a comparison of violations of the monthly geometric mean criterion cannot be conducted.

Table 5.16. Simulated and observed geometric means and violation rates for the calibration location in upper watershed of the North Fork of the Shenandoah River.

Station ID	BNFS093.53	
	Observed	Simulated
Instantaneous Standard Violation Rate	8%	24%
Geometric Mean of All Data Points (cfu/100 mL)	120	156

Table 5.17. Simulated and observed geometric means and violation rates for the calibration location in lower watershed of the North Fork of the Shenandoah River.

Station ID	BNFS054.7	
	Observed	Simulated
Instantaneous Standard Violation Rate	44%	51%
Geometric Mean of All Data Points (cfu/100 mL)	333	395

Table 5.18. Simulated and observed geometric means and violation rates for the calibration location in Stony Creek.

Station ID	BSTY001.22	
	Observed	Simulated
Instantaneous Standard Violation Rate	39%	33%
Geometric Mean of All Data Points (cfu/100 mL)	233	249

Table 5.19. Simulated and observed geometric means and violation rates for the three calibration locations in Mill Creek.

Station ID	MIL002.20	
	Observed	Simulated
Instantaneous Standard Violation Rate	42%	38%
Geometric Mean of All Data Points (cfu/100 mL)	333	277

The final parameters used in the calibration and validation hydrology and water quality simulations are listed in Table 5.20.

Table 5.20. Final calibrated parameters for North Fork of Shenandoah River, Stony Creek, and Mill Creek.

Parameter	Definition	Units	FINAL CALIBRATION	FUNCTION OF...	Appendix Table (if applicable)
PERLND					
PWAT-PARM2					
FOREST	Fraction forest cover	none	1.0 forest, 0.0 other	Forest cover	
LZSN	Lower zone nominal soil moisture storage	inches	5.0	Soil properties	
INFILT	Index to infiltration capacity	in/hr	0.01-0.51 ^a	Soil and cover conditions	1
LSUR	Length of overland flow	feet	100-503	Topography	1
SLSUR	Slope of overland flowplane	none	0.009-0.362	Topography	1
KVARY	Groundwater recession variable	1/in	0.0	Calibrate	
AGWRC	Base groundwater recession	none	0.99 forest, 0.98 other	Calibrate	
PWAT-PARM3					
PETMAX	Temp below which ET is reduced	deg. F	40	Climate, vegetation	
PETMIN	Temp below which ET is set to zero	deg. F	35	Climate, vegetation	
INFEXP	Exponent in infiltration equation	none	2	Soil properties	
INFILD	Ratio of max/mean infiltration capacities	none	2	Soil properties	
DEEPFR	Fraction of GW inflow to deep recharge	none	0.06	Geology	
BASETP	Fraction of remaining ET from baseflow	none	0	Riparian vegetation	
AGWETP	Fraction of remaining ET from active GW	none	0	Marsh/wetlands ET	
PWAT-PARM4					
CEPSC	Interception storage capacity	inches	monthly ^b	Vegetation	2
UZSN	Upper zone nominal soil moisture storage	inches	monthly ^b	Soil properties	3
NSUR	Mannings' n (roughness)	none	0.2 residential, 0.3 pasture, 0.35 crop, 0.45 forest	Land use, surface condition	
INTFW	Interflow/surface runoff partition parameter	none	3.0	Soils, topography, land use	
IRC	Interflow recession parameter	none	0.6	Soils, topography, land use	
LZETP	Lower zone ET parameter	none	monthly ^b	Vegetation	4

Table 5.20. Final calibrated parameters for North Fork of Shenandoah River, Stony Creek, and Mill Creek. (continued)

Parameter	Definition	Units	FINAL CALIBRATION	FUNCTION OF...	Appendix Table (if applicable)
QUAL-INPUT					
SQO	Initial storage of constituent	#/ac	0x10 ^{10c}	Land use	
POTFW	Washoff potency factor	#/ton	0		
POTFS	Scour potency factor	#/ton	0		
ACQOP	Rate of accumulation of constituent	#/day	monthly ^b	Land use	5
SQOLIM	Maximum accumulation of constituent	#	9 x ACQOP ^b	Land use	6
WSQOP	Wash-off rate	in/hr	2.4	Land use	
IOQC	Constituent conc. in interflow	#/ft3	16997 residential, 8496 other	Land use	
AOQC	Constituent conc. in active groundwater	#/ft3	11331 residential, 5664 other	Land use	
IMPLND					
IWAT-PARM2					
LSUR	Length of overland flow	feet	250	Topography	
SLSUR	Slope of overland flowplane	none	0.18	Topography	
NSUR	Mannings' n (roughness)	none	0.1	Land use, surface condition	
RETSC	Retention/interception storage capacity	inches	0.125	Land use, surface condition	
IWAT-PARM3					
PETMAX	Temp below which ET is reduced	deg. F	40	Climate, vegetation	
PETMIN	Temp below which ET is set to zero	deg. F	35	Climate, vegetation	
IQUAL					
SQO	Initial storage of constituent	#/ac	1x10 ⁷		
POTFW	Washoff potency factor	#/ton	0		
ACQOP	Rate of accumulation of constituent	#/day	1x10 ⁷	Land use	
SQOLIM	Maximum accumulation of constituent	#	3x10 ⁷	Land use	
WSQOP	Wash-off rate	in/hr	1.0	Land use	
RCHRES					
HYDR-PARM2					
KS	Weighting factor for hydraulic routing		0.3		
GQUAL					
FSTDEC	First order decay rate of the constituent	1/day	1.80		
THFST	Temperature correction coeff. for FSTDEC		1.05		

^aVaries with land use

^bVaries by month and with land use

^cnote that the simulation was started seven years in advance of calibration to initialize storage

Chapter 6: TMDL ALLOCATIONS

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that the appropriate control actions can be taken to achieve water quality standards (USEPA, 1991). The local steering committee for the three watersheds reviewed and assisted in the final selection of the reduction scenarios for the TMDL plans.

6.1. Bacteria TMDL

6.1.1. Background

The objective of the bacteria TMDL for Mill Creek, Stony Creek, and the North Fork of the Shenandoah River was to determine what reductions in fecal coliform and *E. coli* loadings from point and nonpoint sources are required to meet state water quality standards. The state water quality standards for *E. coli* used in the development of the TMDL were 126 cfu/100mL (calendar-month geometric mean) and 235 cfu/100mL (single sample maximum). The TMDL considers all sources contributing fecal coliform and *E. coli* to the water bodies. The sources can be separated into nonpoint and point (or direct) sources. The incorporation of the different sources into the TMDL are defined in the following equation:

$$\text{TMDL} = \text{WLA} + \text{LA} + \text{MOS} \quad [6.1]$$

where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (nonpoint source contributions); and

MOS = margin of safety.

While developing allocation scenarios to implement the bacteria TMDL, an implicit margin of safety (MOS) was used by using conservative estimations of all factors that would affect the bacteria loadings in the watershed (e.g., animal numbers, production rates, and contributions to streams). These factors were

estimated in such a way as to represent the worst-case scenario; i.e., these factors would describe the worst stream conditions that could exist in the watershed. Creating a TMDL with these conservative estimates ensures that the worst-case scenario has been considered and that no water quality standard violations will occur if the TMDL plan is followed.

When developing a bacteria TMDL, the required bacteria load reductions are modeled by decreasing the amount of bacteria applied to the land surface; these reductions are presented in the tables in Sections 6.1.2b, 6.1.3b, and 6.1.4b. In the model, this has the effect of reducing the amount of bacteria that reaches the stream, the ultimate goal of the TMDL. Thus, the reductions called for in Sections 6.1.2, 6.1.3, and 6.1.4 indicate the need to decrease the amount of bacteria reaching the stream in order to meet the applicable water quality standard. The reductions shown in Sections 6.1.2, 6.1.3, and 6.1.4 are not intended to infer that agricultural producers should reduce their herd size, or limit the use of manures as fertilizer or soil conditioner. Rather, it is assumed that the required reductions from affected agricultural source categories (cattle direct deposit, cropland, etc.) will be accomplished by implementing BMPs like filter strips, stream fencing, and off-stream watering; and that required reductions for from residential source categories will be accomplished by repairing aging septic systems, eliminating straight pipe discharges, and other appropriate measures included in the TMDL Implementation Plan.

For Mill Creek, Stony Creek River, and the North Fork of the Shenandoah, a 6 year source allocation period (1992 to 1997) was used. This period was used due to the restrictions of simulation periods of inflowing watersheds with previously developed TMDL plans. The weather for the period was taken from observed data from the nearby Dale Enterprise weather station. This period was selected because it incorporates average rainfall, low rainfall, and high rainfall years; and the climate during this period caused a wide range of hydrologic events including both low and high flow conditions.

The calendar-month geometric mean values used in this report are geometric means of the simulated daily concentrations. Because HSPF was operated with a one-hour time step in this study, 24 hourly concentrations were generated each day. To estimate the calendar-month geometric mean from the hourly HSPF output, we took the arithmetic mean of the hourly values on a daily basis, and then calculated the geometric mean from these average daily values.

The guidance for developing an *E. coli* TMDL offered by VADEQ is to develop input for the model using fecal coliform loadings as the bacteria source in the watershed. Then, VADEQ suggests the use of a translator equation they developed to convert the daily average fecal coliform concentrations output by the model to daily average *E. coli* concentrations. The translator equation is:

$$E. coli \text{ concentration} = 2^{-0.0172} \times (\text{FC concentration})^{0.91905} \quad [9.2]$$

where the bacteria concentrations (FC and *E. coli*) are in cfu/100mL.

This equation was used to convert the fecal coliform concentrations output by HSPF to *E. coli* concentrations. Daily *E. coli* loads were obtained by using the *E. coli* concentrations calculated from the translator equation and multiplying them by the average daily flow. Annual loads were obtained by summing the daily loads and dividing by the number of years in the allocation period.

6.1.2. Mill Creek Bacteria TMDL

6.1.2.a. Existing Conditions

Analysis of the simulation results for the existing conditions in the watershed (Table 6.1) show that contributions from pervious land segments are the primary source of *E. coli* in the stream. Contributions from the upland pervious land segments account for approximately 94% of the concentration at the watershed outlet. Direct deposition of manure by cattle into Mill Creek is responsible for approximately 5% of the mean daily *E. coli* concentration. The next largest contributors are direct deposits to streams by wildlife (1%). Straight pipes and runoff from impervious areas contributed less than 1% of the mean daily *E. coli* concentration.

Table 6.1. Relative contributions of different *E. coli* sources to the overall *E. coli* concentration for the existing conditions in the Mill Creek watershed.

Source	Mean Daily <i>E. coli</i> Concentration by Source, cfu/100mL	Relative Contribution by Source
All Sources	320	-
Nonpoint source loadings from pervious land segments	301	94%
Direct deposits of cattle manure to stream	16	5%
Direct nonpoint source loadings to the stream from wildlife	3	1%
Straight-pipe discharges to stream	NA	NA
Nonpoint source loadings from impervious land use	<1	<1%

The contribution of each of the sources detailed in Table 6.1 to the calendar-month geometric *E. coli* concentration is shown in Figure 6.1. As indicated in this figure, the calendar-month geometric mean value is dominated by upland pervious land segments and contributions from direct deposits of cattle to streams. In-stream *E. coli* concentrations from direct nonpoint sources, particularly cattle in streams, are highest during the summer when stream flows are lowest. This is expected because cattle tend to spend more time in streams during the summer months; because of the low flow conditions, there is less stream flow for dilution of the direct deposit manure load.

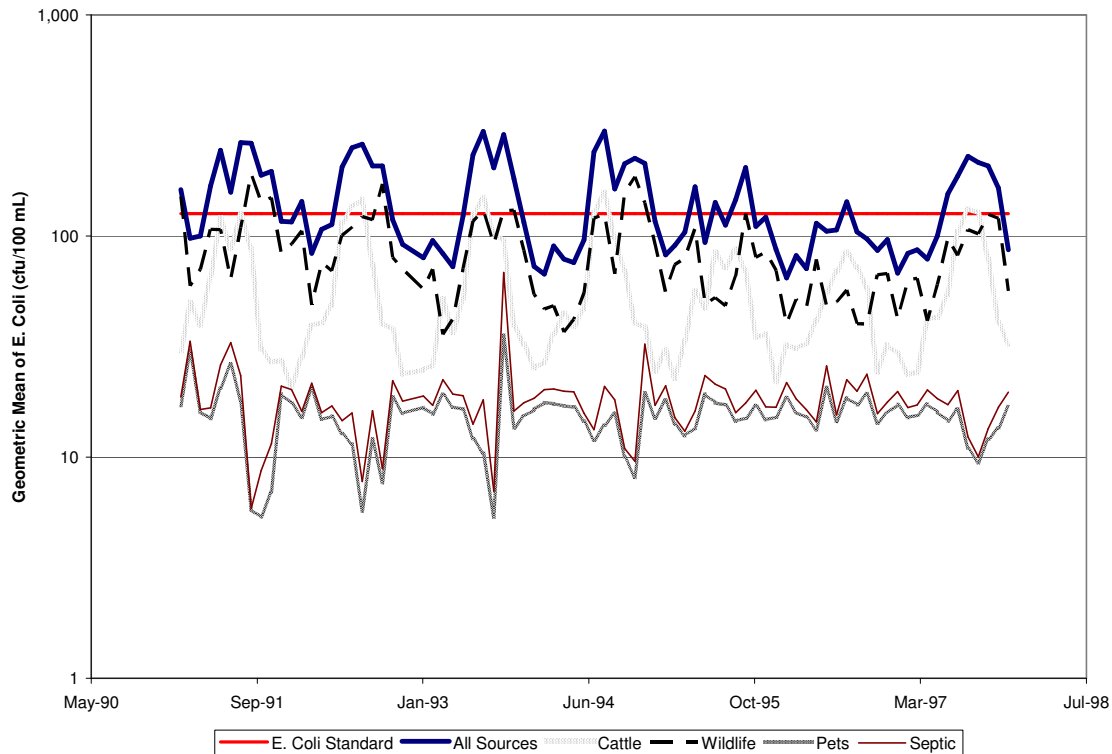


Figure 6.1. Relative contributions of different *E. coli* sources to the calendar-month geometric mean *E. coli* concentration for existing conditions in the Mill Creek watershed.

6.1.2.b. Allocation Scenarios

A variety of allocation scenarios were evaluated to meet the *E. coli* TMDL goal of a calendar-month geometric mean of 126 cfu/100mL and the single sample limit of 235 cfu/100mL. The scenarios and results are summarized in Table 6.2; recall that these reductions are those used for modeling, and implementation of these reductions will require implementation of BMPs as discussed at the beginning of this chapter. Because direct deposition of *E. coli* by cattle into streams was responsible the vast majority of the calendar-month geometric mean concentration, all scenarios considered required reductions in, or elimination of, direct deposits by cattle.

In all scenarios considered in Table 6.2, non-permitted straight-pipe contributions from on-site waste disposal systems were eliminated because these contributions are illegal under existing state law. Nonpoint source contributions from impervious land segments were neglected because their contribution to the calendar-month geometric mean and the daily average

concentrations is negligible (Table 6.1). In scenario 01, straight-pipes were eliminated and large reductions (at least 90%) were taken for cattle direct deposit and (20%) and from land surface loads (cropland and pasture). This had a marginal effect, decreasing the violations of the geometric mean and instantaneous standards (Table 6.2). For scenarios 02 through 04, reductions in cattle direct deposit and overland sources were increased while still not meeting the standard. Scenario 06 meets both *E. coli* standards. Scenario 06 was selected as the TMDL allocation because it does not call for a reduction in wildlife direct-deposit. The concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 6.2 for the TMDL allocation (Scenario 05), along with the standards.

Table 6.2. Bacteria allocation scenarios for the Mill Creek watershed.

Scenario Number	% Violation of <i>E. coli</i> standard		Required Fecal Coliform Loading Reductions to Meet the <i>E. coli</i> Standards,%						
	Geomean	Single Sample	Cattle DD	Cropland	Pasture	Loafing Lot	Wildlife DD	Straight Pipes	All Residential PLS
Existing Conditions	44%	22%	--	--	--	--	--	--	--
01	32%	12%	90	20	20	NA	0	100	0
02	30%	10%	95	20	20	NA	0	100	50
03	28%	8%	95	50	50	NA	0	100	70
04	22%	8%	100	50	50	NA	0	100	70
05	0%	2%	100	80	80	NA	50	100	80
06	0%	0%	85	90	90	NA	50	100	90

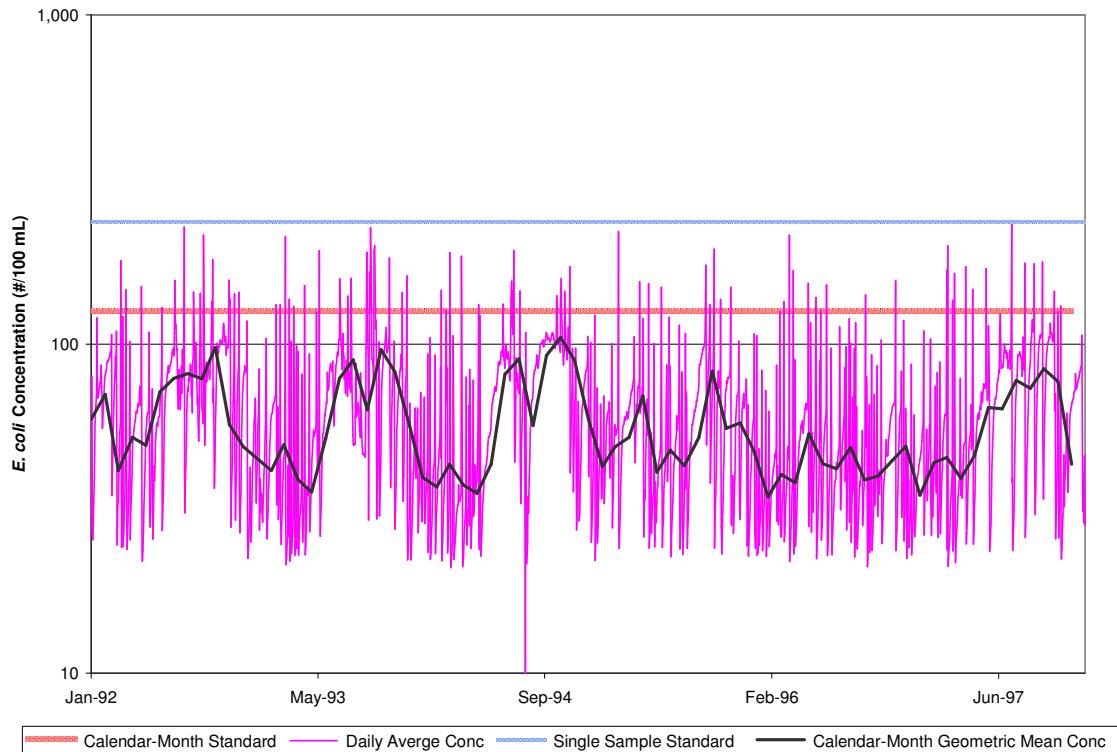


Figure 6.2. Calendar-month geometric mean standard, single sample standard, and successful *E. coli* TMDL allocation (Allocation Scenario 06 from Table 6.2) for Mill Creek.

Loadings for existing conditions and the TMDL allocation scenario (Scenario 06) are presented for nonpoint sources by land use in Table 6.3 and for direct nonpoint sources in Table 6.4. It is clear that extreme reductions in both loadings from land surfaces and from sources directly depositing in the streams of Mill Creek are required to meet both the calendar-month geometric mean and single sample standards for *E. coli*. Cattle deposition directly in streams dominates the *E. coli* contributions to the stream, particularly during the summer months when cattle spend more time in the stream, flows are lower, and there is minimum dilution due to reduced stream flow. Loadings from upland areas are reduced during these periods because there is little upland runoff to transport fecal coliform to streams. When high flow conditions do occur, however, the large magnitude of the nonpoint source loadings coming from upland areas becomes a major contributor to the in-stream concentration. Because these upland loadings are intermittent, they are not a primary source of

violations of the calendar-month geometric mean standard, but do cause many violations of the *E. coli* single sample standard.

Table 6.3. Annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario (Scenario 06).

Land use Category	Existing Conditions		Allocation Scenario	
	Existing conditions load ($\times 10^{12}$ cfu)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($\times 10^{12}$ cfu)	Percent reduction from existing load
Cropland	130	<1%	13	90%
Pasture	27,219	98%	2,722	90%
Residential ^a	20	<1%	2	90%
Forest	168	<1%	168	0%
Total	27,537	100%	2,905	89%

^a Includes loads applied to both High and Low Density Residential

Table 6.4. Annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario (Scenario 06).

Source	Existing Condition		Allocation Scenario	
	Existing conditions load ($\times 10^{12}$ cfu)	Percent of total direct deposited load from direct nonpoint sources	TMDL direct nonpoint source allocation load ($\times 10^{12}$ cfu)	Percent reduction
Cattle in streams	44	65%	7	85%
Straight Pipes	NA	NA%	NA	NA
Wildlife in Streams	24	35%	12	50%
Total	68	100%	19	76%

The fecal coliform loads presented in Table 6.3 and Table 6.4 are the fecal coliform loads that result in in-stream *E. coli* concentrations that meet the applicable *E. coli* water quality standards after application of the VADEQ fecal coliform to *E. coli* translator to the HSPF predicted mean daily fecal coliform concentrations.

6.1.2.c. Waste Load Allocation

Waste load allocations were assigned to the eight general permit point sources located in the Mill Creek watershed (Table 6.5). The point source was represented in the allocation scenarios by its current permit conditions; no reductions were required from the point source in the TMDL. Current permit requirements are expected to result in attainment of the *E. coli* WLA as required

by the TMDL. Point source contributions, even in terms of maximum flow, are minimal. Therefore, no reasonable potential exists for these facilities to have a negative impact on water quality and there is no reason to modify the existing permits. The point source facilities are discharging at their criteria and therefore cannot cause a violation of the water quality criteria.

Table 6.5. Point Sources Discharging Bacteria in the Mill Creek Watershed.

Permitted Discharges	Flow (MGD)	Permitted FC Conc.	Permitted FC Load (cfu/year)	Allocated FC Load (cfu/year)	Allocated <i>E. coli</i> Load (WLA) (cfu/year)
8 Single Family Homes	0.008	200 cfu/100 mL	1.39×10^{10}	1.39×10^{10}	0.88×10^{10}

6.1.2.d. Summary of Mill Creek's TMDL Allocation Scenario for Bacteria

A TMDL for *E. coli* has been developed for Mill Creek. The TMDL addresses the following issues:

1. The TMDL meets the calendar-month geometric mean and single sample water quality standards.
2. Because *E. coli* loading data were not available to quantify point or nonpoint source bacterial loads, available fecal coliform loading data were used as input to HSPF. HSPF was then used to simulate in-stream fecal coliform concentrations. The VADEQ fecal coliform to *E. coli* concentration translator was then used to convert the simulated fecal coliform concentrations to *E. coli* concentrations for which the bacteria TMDL was developed.
3. The TMDL was developed taking into account all fecal bacteria sources (anthropogenic and natural) from both point and nonpoint sources.
4. An implicit margin of safety (MOS) was incorporated by utilizing professional judgment and conservative estimates of model parameters.

5. Both high- and low-flow stream conditions were considered while developing the TMDL. In the Mill Creek watershed, low stream flow was found to be the environmental condition most likely to cause a violation of the geometric mean criterion; however, because the TMDL was developed using a continuous simulation model, it applies to both high- and low-flow conditions. Violations of the instantaneous criterion were associated primarily with storm flows.
6. Both the flow regime and bacteria loading to Mill Creek are seasonal. The TMDL accounts for these seasonal effects.

The selected *E. coli* TMDL allocation that meets both the calendar-month geometric mean and single sample water quality goals requires a 85% reduction in direct deposits of cattle manure and 50% reduction in direct deposits of wildlife manure to streams, elimination of all unpermitted straight-pipe discharges, a 90% reduction in nonpoint source loadings to cropland, pasture, and residential areas. Using Eq. [6.1], the summary of the bacteria TMDL for Mill Creek for the selected allocation scenario (Scenario 06) is given in Table 6.6. In Table 6.6, the WLA was obtained by multiplying the permitted point source's fecal coliform discharge concentration by its allowable annual discharge. The LA is then determined as the TMDL – WLA.

Table 6.6. Annual *E. coli* loadings (cfu/year) at the watershed outlet used for the Mill Creek bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS	TMDL
<i>E. coli</i>	0.01×10^{12}	$1,988 \times 10^{12}$	NA	$1,988.01 \times 10^{12}$

NA - Not Applicable because MOS was implicit

6.1.3. Stony Creek Bacteria TMDL

6.1.3.a. Existing Conditions

Analysis of the simulation results for the existing conditions in the watershed (Table 6.7) show that cattle nonpoint source loadings from pervious land segments (manure applied to cropland, pastures, and forests by livestock,

wildlife, and other NPS sources) to streams is the primary source of *E. coli* in the stream, accounting for 68% of the mean daily *E. coli* in the stream. Loading from cattle directly depositing into streams are the next largest contributors of *E. coli* in the stream, accounting for 20% of daily *E. coli* concentrations. Next is wildlife with 10% of the mean daily in-stream *E. coli* concentration; then straight pipes contributing 2%. Nonpoint source loadings from impervious areas are responsible for less than 1% of the mean daily *E. coli* concentration.

Table 6.7. Relative contributions of different *E. coli* sources to the overall *E. coli* concentration for the existing conditions in the Stony Creek watershed.

Source	Mean Daily <i>E. coli</i> Concentration by Source, cfu/100mL	Relative Contribution by Source
All sources	335	
Nonpoint source loadings from pervious land segments	228	68%
Direct deposits of cattle manure to stream	67	20%
Direct nonpoint source loadings to the stream from wildlife	34	10%
Straight-pipe discharges to stream	7	2%
Nonpoint source loadings from impervious land use	<1	<1%

As shown in Table 6.7, direct *E. coli* loadings from pervious upland areas result in higher mean daily *E. coli* concentrations (1,321 cfu/100 mL) than do *E. coli* loadings by cattle in the stream (386 cfu/100 mL). The contribution of each of these sources to the calendar-month geometric *E. coli* concentration is shown in Figure 6.3. As indicated in this figure, the calendar-month geometric mean value is dominated by contributions from direct deposits of cattle to streams, and these deposits alone result in many violations of the calendar-month geometric mean goal of 126 cfu/100mL. In-stream *E. coli* concentrations from direct nonpoint sources, particularly cattle in streams, are highest during the summer when stream flows are lowest. This is expected because cattle spend more time in streams during the summer months; because of the low flow conditions, there is less stream flow for dilution of the direct deposit manure load. The same is true for the direct deposit from wildlife, to a lesser extent. The violations due to

direct deposits from wildlife throughout the allocation period suggest that reductions in wildlife loadings will be required in the final TMDL allocation. Finally, the calendar-month geometric means for impervious land segments were so low they were not included in Figure 6.3.

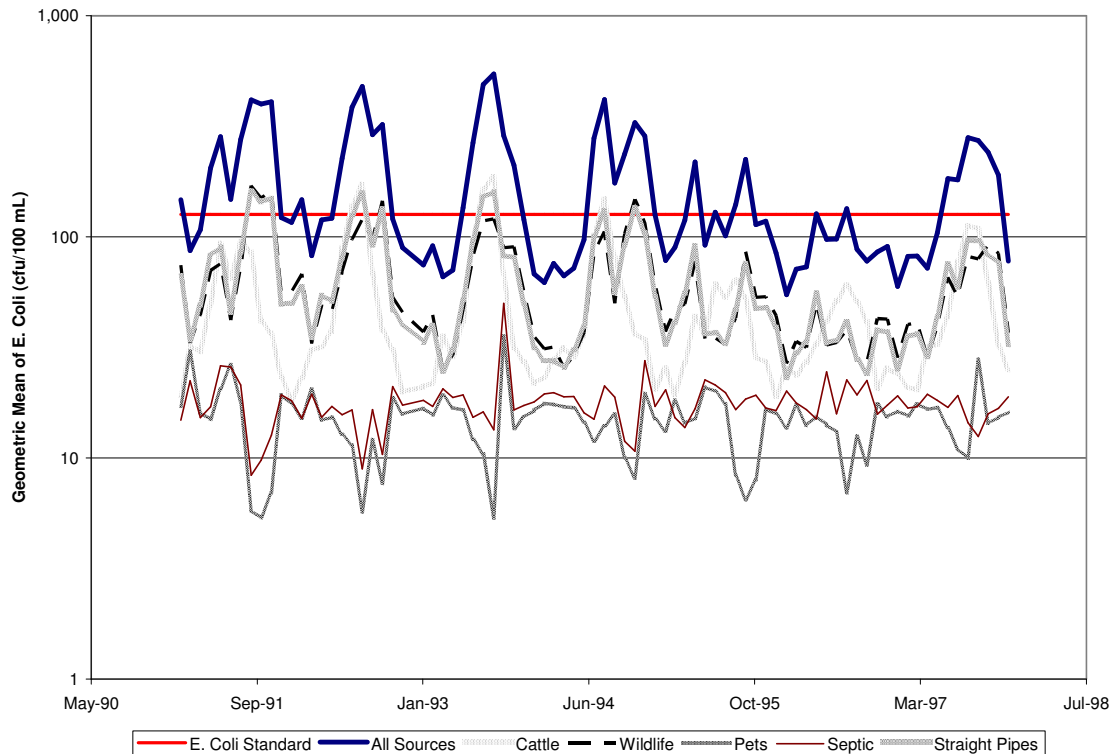


Figure 6.3. Relative contributions of different *E. coli* sources to the calendar-month geometric mean *E. coli* concentration for existing conditions in the Stony Creek watershed.

6.1.3.b. Allocation Scenarios

A variety of allocation scenarios were evaluated to meet the *E. coli* TMDL goal of a calendar-month geometric mean of 126 cfu/100mL and the single sample limit of 235 cfu/100mL. The scenarios and results are summarized in Table 6.8; recall that these reductions are those used for modeling, and implementation of these reductions will require implementation of BMPs as discussed at the beginning of this chapter. Because direct deposition of *E. coli* by cattle into streams was responsible for 60% of the mean daily *E. coli* concentration (Table 9.6), and almost all of the calendar-month geometric mean

concentration, all scenarios considered required large reductions of direct deposits by cattle to the stream.

In all the proposed scenarios, reductions in wildlife direct-deposit to streams were minimized to ensure a practically implementable scenario. An initial attempt at moderate reductions (45% reduction in cattle direct deposit, 50% for all other source categories but wildlife, and elimination of straight pipes, Scenario 01) yielded violations in the geometric mean and instantaneous standards, indicating that larger source reductions would likely be necessary to meet the water quality standard. Successive reductions in sources from cropland, pastured and residential sources resulted in fewer violations. The large reductions in cropland, pastured, and residential sources resulted in zero violations in the single sample standard and a reduction for cattle direct deposit needed was decreased from 100% to 95%. Scenario 06 was selected as reductions in wildlife direct-deposit were not necessary.

The concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 9.4 for the TMDL allocation (Scenario 06), along with the standards.

Table 6.8. Bacteria allocation scenarios for Stony Creek watershed.

Scenario Number	% Violation of <i>E. coli</i> standard		Required Fecal Coliform Loading Reductions to Meet the <i>E. coli</i> Standards, %						
	Geomean	Single Sample	Cattle DD	Cropland	Pasture	Loafing Lot	Wildlife DD	Straight Pipes	All Residential PLS
Existing Conditions	46%	30%	--	--	--	--	--	--	--
01	30%	10%	45	50	50	NA	0	100	50
02	29%	10%	50	50	50	NA	0	100	50
03	28%	7%	50	60	60	NA	0	100	60
04	27%	7%	70	60	60	NA	0	100	60
05	26%	6%	70	80	80	NA	0	100	80
06	0%	0%	95	90	90	NA	70	100	90

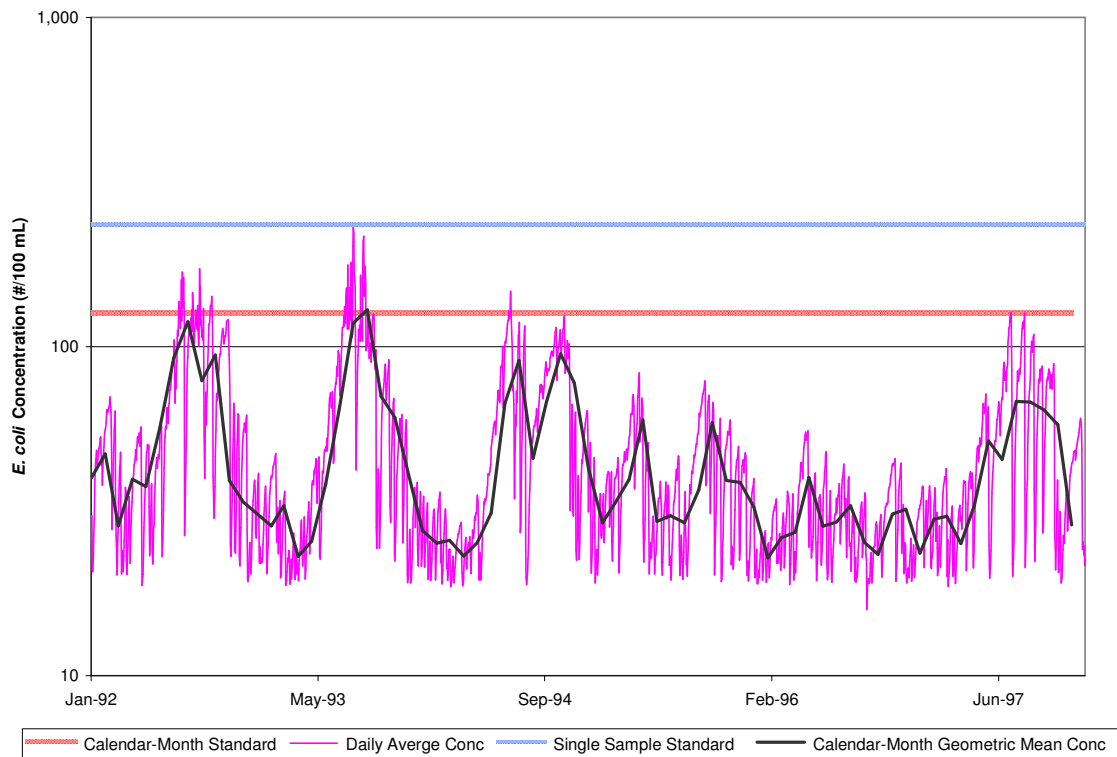


Figure 6.4. Calendar-month geometric mean standard, single sample standard, and successful *E. coli* TMDL allocation (Allocation Scenario 06 from Table 6.8)

Loadings for existing conditions and for the successful TMDL allocation scenario (Scenario 06) are presented for nonpoint sources by land use in Table 6.9 and for direct nonpoint sources in Table 6.10. It is clear that extreme reductions in both loadings from land surfaces and from sources directly depositing in the streams of Stony Creek are required to meet both the calendar-month geometric mean and single sample standards for *E. coli*. Cattle deposition directly in streams dominates the *E. coli* contributions to the stream, particularly during the summer months when cattle spend more time in the stream, flows are lower, and there is minimum dilution due to reduced stream flow. Loadings from upland areas are reduced during these periods because there is little upland runoff to transport fecal coliform to streams. When high flow conditions do occur, however, the large magnitude of the nonpoint source loadings coming from upland areas will result in violations of the water quality standard. Because these upland loadings are intermittent, they are not a primary source of violations of the calendar-month geometric mean standard, but do cause many violations of the *E. coli* single sample standard.

Table 6.9. Annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario (Scenario 06).

Land use Category	Existing Conditions		Allocation Scenario	
	Existing conditions load ($\times 10^{12}$ cfu)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($\times 10^{12}$ cfu)	Percent reduction from existing load
Cropland	282	1%	28	90%
Pasture	52,488	98%	5,249	90%
Residential^a	45	<1%	5	90%
Forest	858	2%	858	0%
Total	53,673	100%	6,140	89%

^a Includes loads applied to both High and Low Density Residential and Farmstead

Table 6.10. Annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario (Scenario 06).

Source	Existing Condition		Allocation Scenario	
	Existing conditions load ($\times 10^{12}$ cfu)	Percent of total direct deposited load from direct nonpoint sources	TMDL direct nonpoint source allocation load ($\times 10^{12}$ cfu)	Percent reduction
Cattle in streams	138	45%	7	95%
Wildlife in Streams	151	49%	45	70%
Straight Pipes	20	6%	0	100%
Total	309	100%	52	83%

The fecal coliform loads presented in Table 6.9 and Table 6.10 are the fecal coliform loads that result in in-stream *E. coli* concentrations that meet the applicable *E. coli* water quality standards after application of the VADEQ fecal coliform to *E. coli* translator to the HSPF predicted mean daily fecal coliform concentrations.

6.1.3.c. Waste Load Allocation

Waste load allocations were assigned to each point source facility in the Stony Creek watershed (Table 6.11). Point sources were represented in the allocation scenarios by their current permit conditions; no reductions were required from point sources in the TMDL. Current permit requirements are expected to result in attainment of the *E. coli* WLA as required by the TMDL. Point source contributions, even in terms of maximum flow, are minimal. Therefore, no reasonable potential exists for these facilities to have a negative impact on water quality and there is no reason to modify the existing permits. The point source facilities are discharging at their criteria and therefore cannot cause a violation of the water quality criteria. Note that the *E. coli* WLA value presented in Table 6.12 represents the sum of all point source *E. coli* WLAs in Stony Creek.

Table 6.11. Point Sources Discharging Bacteria in the Stony Creek Watershed.

Permitted Discharges	Flow (MGD)	Permitted FC Conc.	Permitted FC Load (cfu/year)	Allocated FC Load (cfu/year)	Allocated <i>E. coli</i> Load (WLA) (cfu/year)
VA0020508	0.175	200 cfu/100 mL	5.12×10^{11}	5.12×10^{11}	3.05×10^{11}
VA0028380	0.600	200 cfu/100 mL	1.74×10^{12}	1.74×10^{12}	1.04×10^{12}
VA0028401	0.039	200 cfu/100 mL	11.4×10^{10}	11.4×10^{10}	6.79×10^{10}
VA0077402	1.700	200 cfu/100 mL	4.96×10^{12}	4.96×10^{12}	2.96×10^{12}
26 Single Family Homes	0.026	200 cfu/100 mL	7.60×10^{10}	7.60×10^{10}	4.53×10^{10}

6.1.3.d. Summary of Stony Creek's TMDL Allocation Scenario for Bacteria

A TMDL for *E. coli* has been developed for Stony Creek. The TMDL addresses the following issues:

1. The TMDL meets the calendar-month geometric mean and single sample water quality standards.
2. Because *E. coli* loading data were not available to quantify point or nonpoint source bacterial loads, available fecal coliform loading data were used as input to HSPF. HSPF was then used to simulate in-stream fecal coliform concentrations. The VADEQ fecal coliform to *E. coli* concentration translator was then used to convert the simulated fecal coliform concentrations to *E. coli* concentrations for which the bacteria TMDL was developed.
3. The TMDL was developed taking into account all fecal bacteria sources (anthropogenic and natural) from both point and nonpoint sources.
4. An implicit margin of safety (MOS) was incorporated by utilizing professional judgment and conservative estimates of model parameters.

5. Both high- and low-flow stream conditions were considered while developing the TMDL. In the Stony Creek watershed, low stream flow was found to be the environmental condition most likely to cause a violation of the geometric mean criterion; however, because the TMDL was developed using a continuous simulation model, it applies to both high- and low-flow conditions. Violations of the instantaneous criterion were associated primarily with storm flows.
6. Both the flow regime and bacteria loading to Stony Creek are seasonal. The TMDL accounts for these seasonal effects.

The selected *E. coli* TMDL allocation that meets both the calendar-month geometric mean and single sample water quality goals requires a 95% reduction in direct deposits of cattle manure to streams, a 70% reduction in direct deposits of wildlife to streams, and a 90% reduction in loadings to all cropland, pasture and residential pervious surfaces, along with elimination of straight pipes. Using Eq. [6.1], the summary of the bacteria TMDL for Stony Creek for the selected allocation scenario (Scenario 06) is given in Table 6.12. In Table 6.12, the WLA was obtained by summing the products of each permitted point source's fecal coliform discharge concentration and allowable annual discharge. The LA is then determined as the TMDL – WLA.

Table 6.12. Annual *E. coli* loadings (cfu/year) used for the Stony Creek bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS	TMDL
<i>E. coli</i>	4.42×10^{12}	$4,210 \times 10^{12}$	NA	$4,214.4 \times 10^{12}$

NA - Not Applicable because MOS was implicit

6.1.4. North Fork of the Shenandoah River Bacteria TMDL

6.1.2.a. Existing Conditions

The contribution of each of the sources detailed in Table 6.13 to the mean daily and calendar-month geometric mean *E. coli* concentration is shown in Figure 6.5. As seen in Table 6.13, the largest contribution to the daily average is from the upstream watershed inflows and these inflows dominate the calendar-

month geometric mean as indicated in Figure 6.5. The loadings from the up stream watershed inflows is large, however, these loads are for the existing conditions of those watersheds. The cattle direct deposit load contributions to the geometric mean concentrations are almost as high as the contributions from upstream watershed inflows for existing conditions.

When the TMDL conditions are applied to upstream watersheds, the overall average decreases and the percent contribution from the inflows dramatically decreases (Table 6.14). More importantly, the calendar-month geometric mean for the inflows does not violate the standard, as would be expected (Figure 6.6). The reductions for the TMDL were made using the inflows for the TMDL conditions of the up stream watersheds.

Table 6.13. Relative contributions of different *E. coli* sources to the overall *E. coli* concentration for the existing conditions in the lower watershed of the North Fork of the Shenandoah River watershed.

Source	Mean Daily <i>E. coli</i> Concentration by Source, cfu/100mL	Relative Contribution by Source
All Sources	722	-
Nonpoint source loadings from pervious land segments	65	9%
Direct deposits of cattle manure to stream	173	24%
Direct nonpoint source loadings to the stream from wildlife	22	3%
Straight-pipe discharges to stream	14	2%
Nonpoint source loadings from impervious land use	<1	<1%
Loadings from Up Stream Watersheds^a	455	63%

^a Up stream watersheds at existing conditions

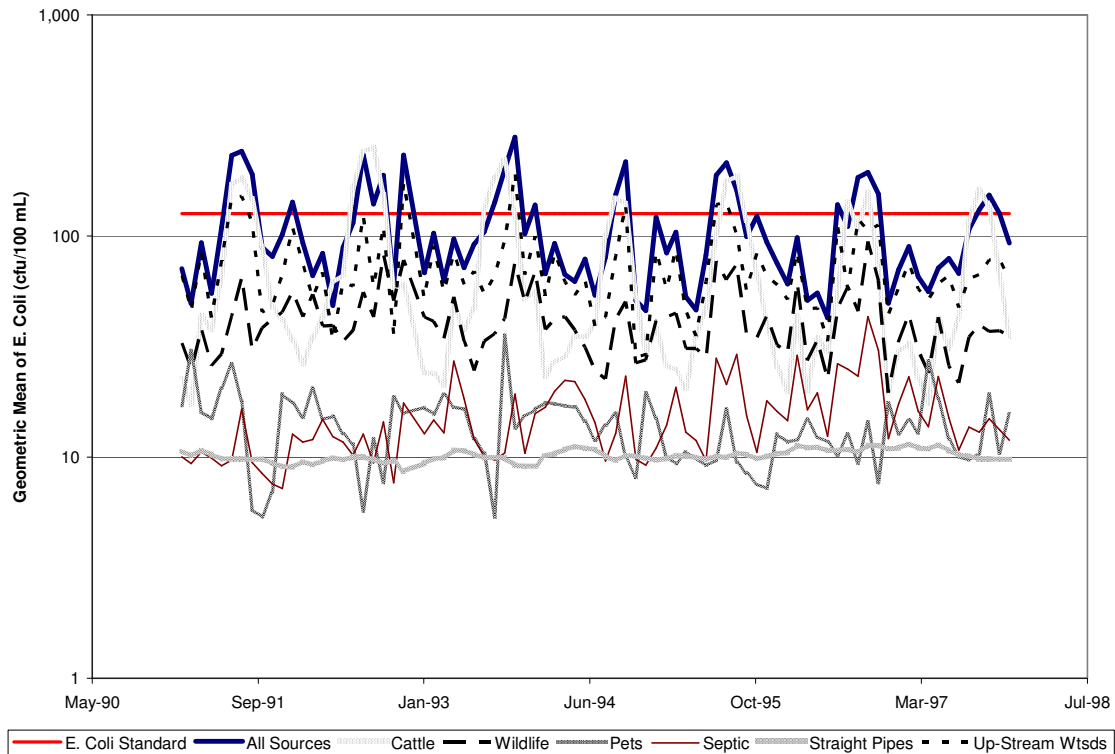


Figure 6.5. Relative contributions of different *E. coli* sources to the calendar-month geometric mean *E. coli* concentration for existing conditions in the lower watershed of the North Fork of the Shenandoah River watershed.

Table 6.14. Relative contributions of different *E. coli* sources to the overall *E. coli* concentration for the existing conditions in the lower watershed of the North Fork of the Shenandoah River watershed and the Upstream watershed outflows set at the Water Quality Standard.

Source	Mean Daily <i>E. coli</i> Concentration by Source, cfu/100mL	Relative Contribution by Source
All Sources	722	-
Nonpoint source loadings from pervious land segments	65	9%
Direct deposits of cattle manure to stream	173	24%
Direct nonpoint source loadings to the stream from wildlife	22	3%
Straight-pipe discharges to stream	14	2%
Nonpoint source loadings from impervious land use	<1	<1%
Loadings from Up Stream Watersheds ^a	455	63%

^a Up stream watersheds outflows at Water Quality Standard Concentration

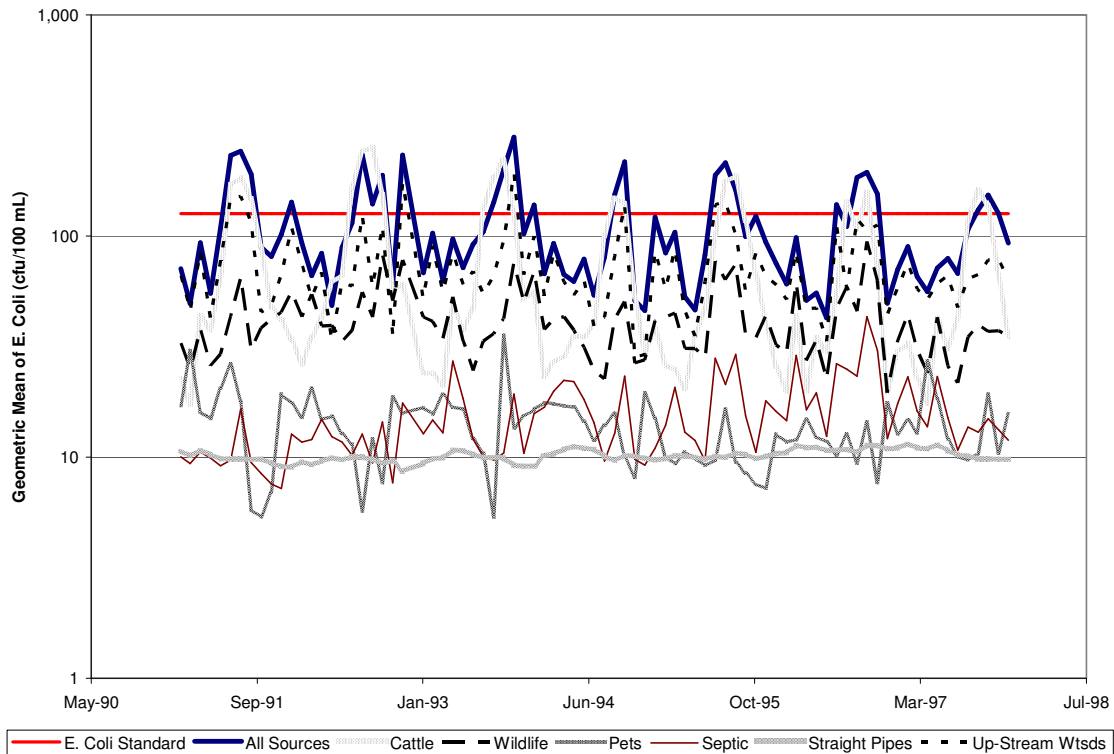


Figure 6.6. Relative contributions of different *E. coli* sources to the calendar-month geometric mean *E. coli* concentration for existing conditions in the lower watershed of the North Fork of the Shenandoah River watershed and the Upstream watershed outflows set at the Water Quality Standard.

As indicated in this figure, the calendar-month geometric mean value is dominated by contributions from direct deposits of cattle to streams and to a lesser extent by upland pervious land segments. In-stream *E. coli* concentrations from direct nonpoint sources, particularly cattle in streams, are highest during the summer when stream flows are lowest. This is expected because cattle tend to spend more time in streams during the summer months; because of the low flow conditions, there is less stream flow for dilution of the direct deposit manure load. Contributions from wildlife direct deposit and from upland pervious areas (PLS) to the calendar month geometric mean concentration are roughly equivalent as shown in Figure 6.6. Contributions straight pipe contributions are significantly lower than the other sources in the graph.

Analysis of the simulation results for the existing conditions in the watershed (Table 6.14) show that contributions from direct deposits of cattle to

streams are the primary source of *E. coli* in the stream. Contributions from the direct deposits of cattle to streams account for approximately 61% of the concentration at the watershed outlet.

6.1.2.b. Allocation Scenarios

A variety of allocation scenarios were evaluated to meet the *E. coli* TMDL goal of a calendar-month geometric mean of 126 cfu/100mL and the single sample limit of 235 cfu/100mL. The scenarios and results are summarized in Table 6.15; recall that these reductions are those used for modeling, and implementation of these reductions will require implementation of BMPs as discussed at the beginning of this chapter. Because direct deposition of *E. coli* by cattle into streams was responsible for 61% of the mean daily *E. coli* concentration (Table 6.14) and the vast majority of the calendar-month geometric mean concentration, all scenarios considered required reductions in, or elimination of, direct deposits by cattle.

In all scenarios considered in Table 6.15, non-permitted straight-pipe contributions from on-site waste disposal systems were eliminated because these contributions are illegal under existing state law. Nonpoint source contributions from impervious land segments were neglected because their contribution to the calendar-month geometric mean and the daily average concentrations is negligible (Table 6.15). In scenario 01, straight-pipes were eliminated and reductions (5%) were taken from direct deposition by cattle. This had a moderate effect on the violations of the geometric mean instantaneous standards (Table 6.15). Scenarios 02 through 05 took increasing reductions from all sources while still not meeting the standard, but reduced the cattle direct deposition. The progression from Scenario 02 to the successful scenarios shows that high reductions are required from PLS areas with small reduction in the violation rates. After increasing the reductions from overland sources (Scenarios 06), both *E. coli* standards were met. The concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 6.2 for the TMDL allocation (Scenario 06), along with the standards.

Table 6.15. Bacteria allocation scenarios for the lower watershed of the North Fork of the Shenandoah River watershed.

Scenario Number	% Violation of <i>E. coli</i> standard		Required Fecal Coliform Loading Reductions to Meet the <i>E coli</i> Standards,%						
	Geomean	Single Sample	Cattle DD	Cropland	Pasture	Loafing Lot	Wildlife DD	Straight Pipes	All Residential PLS
Existing Conditions	29%	51%	--	--	--	NA	--	--	--
1	2%	9%	5	15	15	NA	0	100	15
2	2%	7%	10	15	15	NA	0	100	15
3	0%	3%	30	30	30	NA	0	100	30
4	0%	1%	30	75	75	NA	0	100	75
5	0%	1%	30	80	80	NA	20	100	80
6	0%	0%	30	85	85	NA	0	100	85

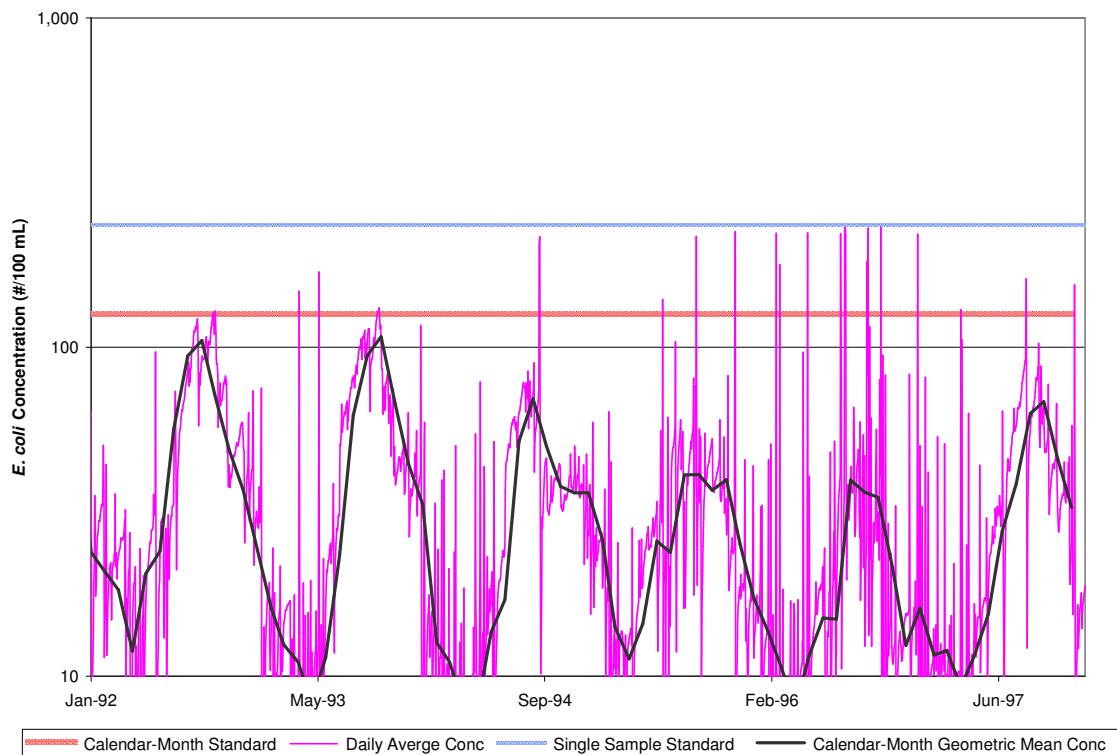


Figure 6.7. Calendar-month geometric mean standard, single sample standard, and successful *E. coli* TMDL allocation (Allocation Scenario 06 from Table 6.15) for the lower watershed of the North Fork of the Shenandoah River watershed.

Loadings for existing conditions and the TMDL allocation scenario (Scenario 06) are presented for nonpoint sources by land use in Table 6.16 and for direct nonpoint sources in Table 6.17. It is clear that extreme reductions in both loadings from land surfaces and from sources directly depositing in the streams are required to meet both the calendar-month geometric mean and single sample standards for *E. coli*. Cattle deposition directly in streams dominates the *E. coli* contributions to the stream, particularly during the summer months when cattle spend more time in the stream, flows are lower, and there is minimum dilution due to reduced stream flow. Loadings from upland areas are reduced during these periods because there is little upland runoff to transport fecal coliform to streams. When high flow conditions do occur, however, the large magnitude of the nonpoint source loadings coming from upland areas becomes a major contributor to the in-stream concentration. Because these

upland loadings are intermittent, they are not a primary source of violations of the calendar-month geometric mean standard, but do cause many violations of the *E. coli* single sample standard.

Table 6.16. Annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario (Scenario 06).

Land use Category	Existing Conditions		Allocation Scenario	
	Existing conditions load ($\times 10^{12}$ cfu)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($\times 10^{12}$ cfu)	Percent reduction from existing load
Cropland	2,439	1%	366	85%
Pasture	192,448	95%	28,867	85%
Residential ^a	5,753	3%	863	85%
Forest	1,320	1%	1,320	0%
Total	201,960	100%	31,416	84%

^a Includes loads applied to both High and Low Density Residential and Farmstead

Table 6.17. Annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario (Scenario 06).

Source	Existing Condition		Allocation Scenario	
	Existing conditions load ($\times 10^{12}$ cfu)	Percent of total direct deposited load from direct nonpoint sources	TMDL direct nonpoint source allocation load ($\times 10^{12}$ cfu)	Percent reduction
Cattle in streams	346	45%	242	30%
Straight Pipes	125	16%	0	100%
Wildlife in Streams	305	39%	305	0%
Total	776	100%	547	29%

The fecal coliform loads presented in Table 6.16 and Table 6.17 are the fecal coliform loads that result in in-stream *E. coli* concentrations that meet the applicable *E. coli* water quality standards after application of the VADEQ fecal coliform to *E. coli* translator to the HSPF predicted mean daily fecal coliform concentrations.

6.1.2.c. Waste Load Allocation

Waste load allocations were assigned to the point source facilities located in the lower watershed of the North Fork of the Shenandoah River watershed (Table 6.18). The point source was represented in the allocation scenarios by its current permit conditions; no reductions were required from the point source in

the TMDL. Current permit requirements are expected to result in attainment of the *E. coli* WLA as required by the TMDL. Point source contributions, even in terms of maximum flow, are minimal. Therefore, no reasonable potential exists for these facilities to have a negative impact on water quality and there is no reason to modify the existing permits. The point source facilities are discharging at their criteria and therefore cannot cause a violation of the water quality criteria.

Table 6.18. Point Sources Discharging Bacteria in the North Fork of the Shenandoah River Watershed.

Permit Number	Flow (MGD)	Permitted FC Conc.	Permitted FC Load (cfu/year)	Allocated FC Load (cfu/year)	Allocated <i>E. coli</i> Load (WLA) (cfu/year)
VA0021342	0.010	200 cfu/100 mL	2.76×10^{10}	2.76×10^{10}	1.74×10^{10}
VA0022853	0.500	200 cfu/100 mL	1.38×10^{12}	1.38×10^{12}	8.70×10^{11}
VA0026441	0.600	200 cfu/100 mL	1.66×10^{12}	1.66×10^{12}	1.04×10^{12}
VA0026468	2.000	200 cfu/100 mL	9.24×10^{12}	9.24×10^{12}	3.48×10^{12}
VA0088846	0.007	200 cfu/100 mL	1.93×10^{10}	1.93×10^{10}	1.22×10^{10}
VA0090263	1.923	200 cfu/100 mL	8.88×10^{12}	8.88×10^{12}	3.35×10^{12}
VA0090328	0.750	200 cfu/100 mL	2.08×10^{12}	2.08×10^{12}	1.31×10^{12}
61 Single Family Homes	0.061	200 cfu/100 mL	1.97×10^{11}	1.97×10^{11}	10.62×10^{10}

6.1.2.d. Summary of lower watershed of the North Fork of the Shenandoah River's TMDL Allocation Scenario for Bacteria

A TMDL for *E. coli* has been developed for lower watershed of the North Fork of the Shenandoah River. The TMDL addresses the following issues:

1. The TMDL meets the calendar-month geometric mean and single sample water quality standards.

2. Because *E. coli* loading data were not available to quantify point or nonpoint source bacterial loads, available fecal coliform loading data were used as input to HSPF. HSPF was then used to simulate in-stream fecal coliform concentrations. The VADEQ fecal coliform to *E. coli* concentration translator was then used to convert the simulated fecal coliform concentrations to *E. coli* concentrations for which the bacteria TMDL was developed.
3. The TMDL was developed taking into account all fecal bacteria sources (anthropogenic and natural) from both point and nonpoint sources.
4. An implicit margin of safety (MOS) was incorporated by utilizing professional judgment and conservative estimates of model parameters.
5. Both high- and low-flow stream conditions were considered while developing the TMDL. In the lower watershed of the North Fork of the Shenandoah River, low stream flow was found to be the environmental condition most likely to cause a violation of the geometric mean criterion; however, because the TMDL was developed using a continuous simulation model, it applies to both high- and low-flow conditions. Violations of the instantaneous criterion were associated primarily with storm flows.
6. Both the flow regime and bacteria loading to lower watershed of the North Fork of the Shenandoah River are seasonal. The TMDL accounts for these seasonal effects.

The selected *E. coli* TMDL allocation that meets both the calendar-month geometric mean and single sample water quality goals requires a 30% reduction in direct deposits of cattle manure to streams, elimination of all unpermitted straight-pipe discharges, a 85% reduction in nonpoint source loadings to cropland, pasture and residential areas, and no reduction direct deposition from wildlife sources. Using Eq. [6.1], the summary of the bacteria TMDL for lower watershed of the North Fork of the Shenandoah River's for the selected allocation scenario (Scenario 06) is given in Table 6.19. In Table 6.19, the WLA

was obtained by multiplying the permitted point source's fecal coliform discharge concentration by its allowable annual discharge. The LA is then determined as the TMDL – WLA.

Table 6.19. Annual *E. coli* loadings (cfu/year) at the watershed outlet used for the lower watershed of the North Fork of the Shenandoah River bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS	TMDL
<i>E. coli</i>	10.18×10^{12}	$21,734 \times 10^{12}$	NA	$21,745 \times 10^{12}$

NA - Not Applicable because MOS was implicit

CHAPTER 7: TMDL IMPLEMENTATION AND REASONABLE ASSURANCE

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and non point sources in the stream (see section 7.4.2). For point sources, all new or revised VPDES/NPDES permits must be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B) and must be submitted to EPA for approval. The measures for non point source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the “TMDL Implementation Plan Guidance Manual”, published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at <http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf>. With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

7.1. Staged Implementation

In general, Virginia intends for the required bacteria reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, the most promising management practice is livestock exclusion from streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the cattle deposits themselves and by providing additional riparian buffers.

Additionally, in both urban and rural areas, reducing the human bacteria loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems.

In urban areas, reducing the human bacteria loading from leaking sewer lines could be accomplished through a sanitary sewer inspection and management program. Other BMPs that might be appropriate for controlling urban wash-off from parking lots and roads and that could be readily implemented may include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning.

The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. While specific goals for BMP implementation will be established as part of the implementation plan development, the following stage 1 scenarios are targeted at controllable, anthropogenic bacteria sources and can serve as starting points for targeting BMP implementation activities.

7.2. Stage 1 Scenarios

The goal of the stage 1 scenarios is to reduce the bacteria loadings from controllable sources (excluding wildlife) such that violations of the single sample maximum criterion (235 cfu/100mL) are less than 10 percent. The stage 1 scenarios were generated with the same model setup as was used for the TMDL allocation scenarios.

7.2.1. Stage 1 Scenario for Mill Creek

The Stage 1 scenario for the Mill Creek watershed is listed Table 7.1. The Stage 1 implementation goal can be reached with 50% reduction in contributions from livestock direct deposits, elimination of straight pipe dischargers, and 50% reductions from upland areas (cropland, pasture and residential). *E. coli* concentrations resulting from application of the fecal coliform to *E. coli* translator equation to the Stage 1 fecal coliform concentrations are presented graphically in Figure 7.1.

Table 7.1. Allocation scenario for Stage 1 TMDL implementation for Mill Creek.

Single Sample Standard Percent Violation	Required Fecal Coliform Loading Reductions to Meet the Stage 1 Goal, %					
	Livestock DD	Loads from Cropland	Loads from Pasture	Wildlife DD	Straight Pipes	Loads from Residential
10	50	50	50	0	NA	50

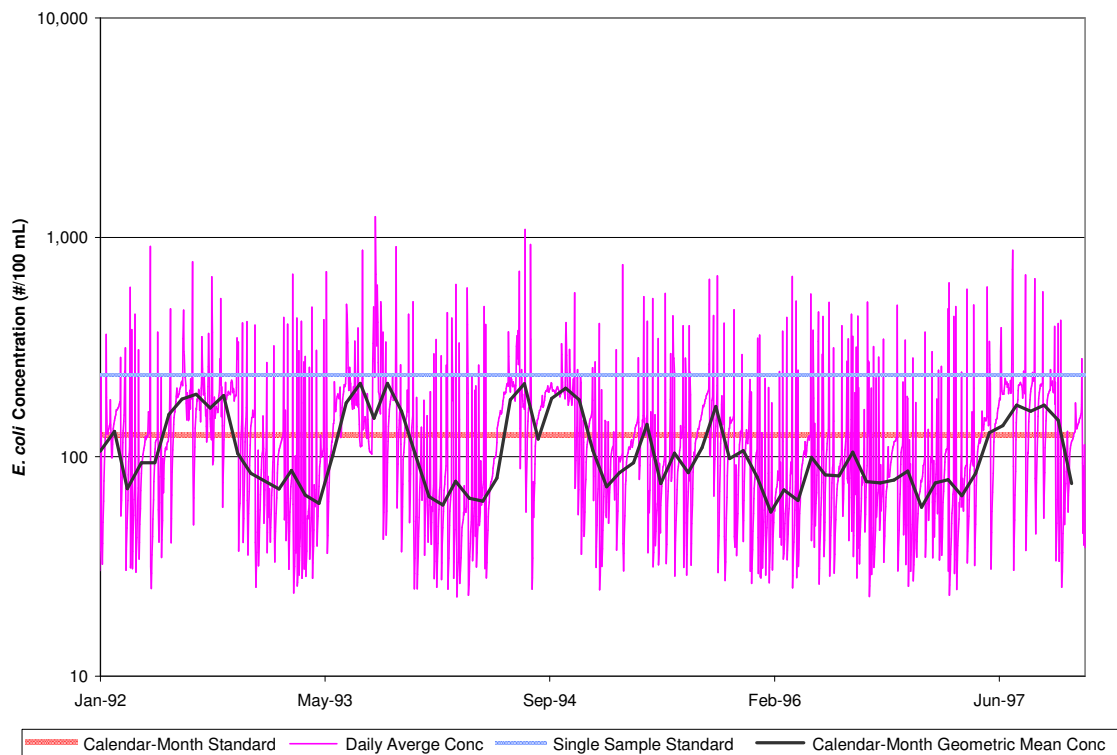


Figure 7.1. Simulated *E. coli* concentrations with the two bacteria standards for the Stage 1 implementation scenario for Mill Creek.

7.2.2. Stage 1 Scenario for Stony Creek

The Stage 1 scenario for the Stony Creek watershed is listed in Table 7.2. The Stage 1 implementation goal can be reached with just 45% reduction in contributions from livestock direct deposits, elimination of straight pipe dischargers, and 50% reductions from upland areas (cropland, pasture and residential). *E. coli* concentrations resulting from application of the fecal coliform to *E. coli* translator equation to the Stage 1 fecal coliform concentrations are presented graphically in Figure 7.2.

Table 7.2. Allocation scenario for Stage 1 TMDL implementation for Stony Creek.

Single Sample Standard Percent Violation	Required Fecal Coliform Loading Reductions to Meet the Stage 1 Goal, %					
	Livestock DD	Loads from Cropland	Loads from Pasture	Wildlife DD	Straight Pipes	Loads from Residential
10	45	50	50	0	100	50

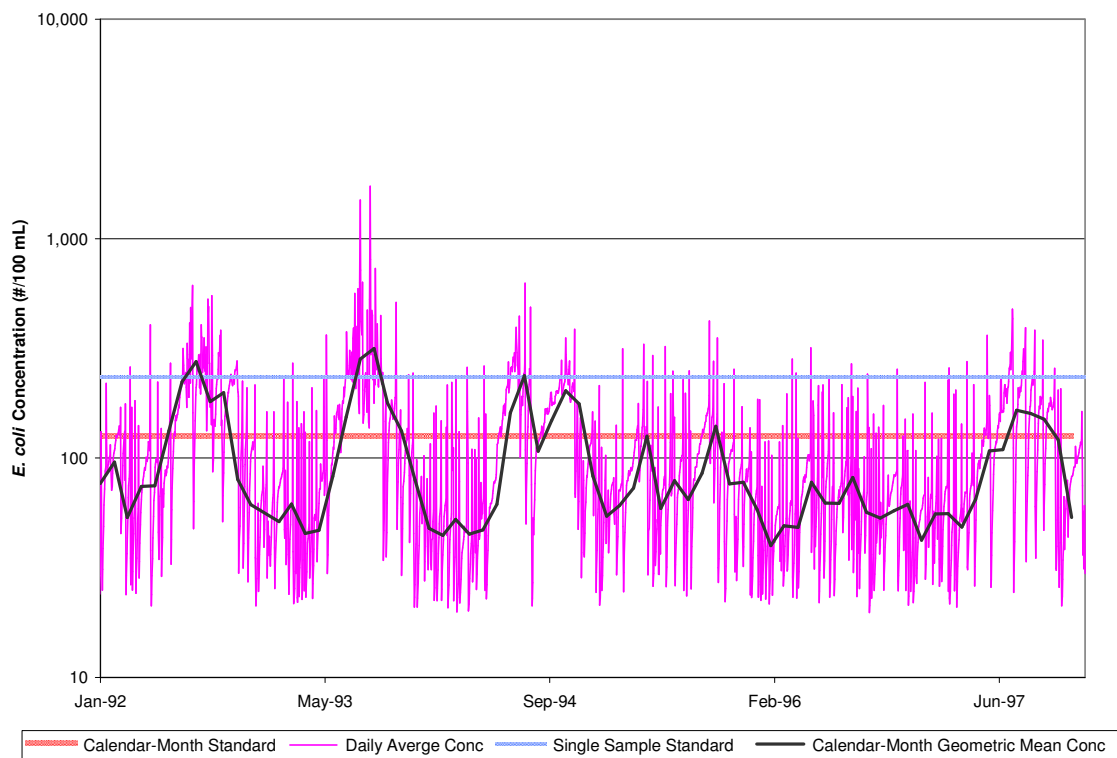


Figure 7.2. Simulated *E. coli* concentrations with the two bacteria standards for the Stage 1 implementation scenario for Stony Creek.

7.2.3. Stage 1 Scenario for lower watershed of the North Fork of the Shenandoah River

The Stage 1 scenario for the lower watershed of the North Fork of the Shenandoah River watershed is listed Table 7.3. The Stage 1 implementation goal can be reached with just 5% reduction in contributions from livestock direct deposits, elimination of straight pipe dischargers and a 15% reduction of overland sources (cropland, pasture, and residential). Also, the Stage 1 implementation includes the implementation of Stage 1 plans in upstream

watersheds. *E. coli* concentrations resulting from application of the fecal coliform to *E. coli* translator equation to the Stage 1 fecal coliform concentrations are presented graphically in Figure 7.3.

Table 7.3. Allocation scenario for Stage 1 TMDL implementation for for lower watershed of the North Fork of the Shenandoah River.

Single Sample Standard Percent Violation	Required Fecal Coliform Loading Reductions to Meet the Stage 1 Goal, %					
	Livestock DD	Loads from Cropland	Loads from Pasture	Wildlife DD	Straight Pipes	Loads from Residential
9	5	15	15	0	100	15

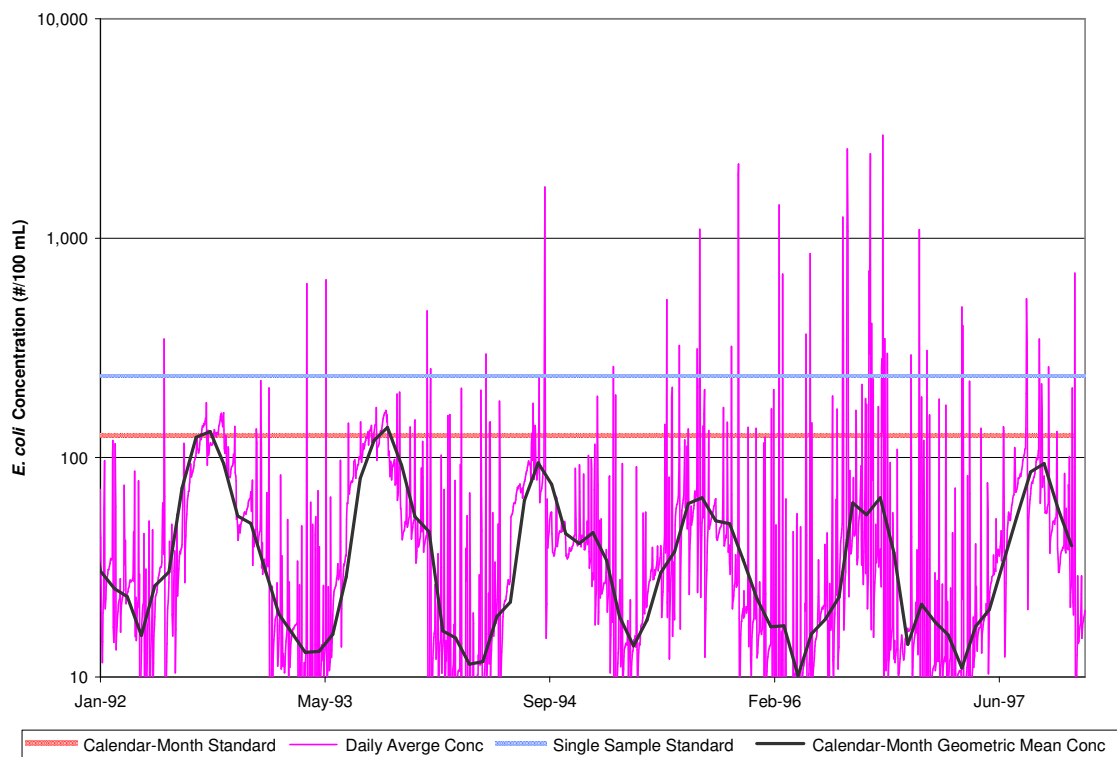


Figure 7.3. Simulated *E. coli* concentrations with the two bacteria standards for the Stage 1 implementation scenario for for lower watershed of the North Fork of the Shenandoah River.

7.3. Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the Chesapeake Bay.

Several BMPs known to be effective in controlling bacteria have also been identified for implementation as part of the Tributary Strategy for the Shenandoah River basin. For example, management of on-site waste management systems, management of livestock and manure, and pet waste management are among the components of the strategy described under nonpoint source implementation mechanisms. Up-to-date information on the tributary strategy implementation process can be found at the tributary strategy web site under <http://www.snr.state.va.us/WaterQuality/FinalizedTribStrats/shenandoah.pdf>.

7.4. Reasonable Assurance for Implementation

7.4.1. Follow-up Monitoring

Following the development of the TMDL, the Department of Environmental Quality (DEQ) will make every effort to continue to monitor the impaired stream in accordance with its ambient monitoring program. DEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with DEQ Guidance Memo No. 03-2004, during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee, and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. At a minimum, the monitoring station must be representative of the original impaired segment. The details of the follow-up monitoring will be outlined in the Annual Water Monitoring Plan prepared by each DEQ Regional Office. Other agency personnel, watershed stakeholders, etc. may provide input

on the Annual Water Monitoring Plan. These recommendations must be made to the DEQ regional TMDL coordinator by September 30 of each year.

DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee, and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants (“water quality milestones” as established in the Implementation Plan), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in DEQ’s standard monitoring plan. Ancillary monitoring by citizens, watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with DEQ monitoring data. In instances where citizens’ monitoring data are not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring managers in each regional office an increase in the number of stations or monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at <http://www.deq.virginia.gov/cmonitor/>.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or TMDL Implementation Plan has been completed), DEQ must meet the minimum data requirement at the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum

requirement is two consecutive samples (one in the spring and one in the fall) in a one year period.

7.4.2. Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. EPA also requires that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B). All such permits should be submitted to EPA for review.

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). WQMIRA also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

For the implementation of the WLA component of the TMDL, the Commonwealth intends to utilize the Virginia NPDES (VPDES) program, which typically includes consideration of the WQMIRA requirements during the permitting process. Requirements of the permit process should not be duplicated in the TMDL process, and with the exception of stormwater related permits, permitted sources are not usually addressed during the development of a TMDL implementation plan.

For the implementation of the TMDL's LA component, a TMDL implementation plan addressing at a minimum the WQMIRA requirements will be developed. An exception are the municipal separate storm sewer systems (MS4s) which are both covered by NPDES permits and expected to be included in TMDL implementation plans, as described in the stormwater permit section below.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan. Regional and local offices of DEQ, DCR, and other cooperating agencies are technical resources to assist in this endeavor.

In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the Water Quality Management Plans (WQMPs). Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

DEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the State Water Control Board for inclusion in the appropriate WQMP, in accordance with the Clean Water Act's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

DEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as is the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on DEQ's web site under <http://www.deq.state.va.us/tmdl/pdf/ppp.pdf>.

7.4.3. Stormwater Permits

DEQ and DCR coordinate separate State programs that regulate the management of pollutants carried by storm water runoff. DEQ regulates storm water discharges associated with "industrial activities", while DCR regulates storm water discharges from construction sites, and from municipal separate storm sewer systems (MS4s).

EPA approved DCR's VPDES storm water program on December 30, 2004. DCR's regulations became effective on January 29, 2005. DEQ is no longer the regulatory agency responsible for administration and enforcement of the VPDES MS4 and construction storm water permitting programs. More information is available on DCR's web site through the following link: <http://www.dcr.virginia.gov/sw/vsmp>.

It is the intention of the Commonwealth that the TMDL will be implemented using existing regulations and programs. One of these regulations is DCR's Virginia Stormwater Management Program (VSMP) Permit Regulation (4 VAC 50-60-10 et. seq). Section 4VAC 50-60-380 describes the requirements for stormwater discharges. Also, federal regulations state in 40 CFR §122.44(k) that NPDES permit conditions may consist of "Best management practices to control or abate the discharge of pollutants when:...(2) Numeric effluent limitations are infeasible,...".

For MS4/VSMP general permits, the Commonwealth expects the permittee to specifically address the TMDL wasteload allocations for stormwater through the implementation of programmatic BMPs. BMP effectiveness would be determined through ambient in-stream monitoring. This is in accordance with recent EPA guidance (EPA Memorandum on TMDLs and Stormwater Permits, dated November 22, 2002). If future monitoring indicates no improvement in stream water quality, the permit could require the MS4 to expand or better tailor its stormwater management program to achieve the TMDL wasteload allocation. However, only failing to implement the programmatic BMPs identified in the modified stormwater management program would be considered a violation of the permit. DEQ acknowledges that it may not be possible to meet the existing

water quality standard because of the wildlife issue associated with a number of bacteria TMDLs (see section 7.4.5 below). At some future time, it may therefore become necessary to investigate the stream's use designation and adjust the water quality criteria through a Use Attainability Analysis. Any changes to the TMDL resulting from water quality standards change on Mill Creek, Stony Creek, and the lower watershed of the North Fork of the Shenandoah River watersheds would be reflected in the permit.

Wasteload allocations for stormwater discharges from storm sewer systems covered by a MS4 permit will be addressed in TMDL implementation plans. An implementation plan will identify types of corrective actions and strategies to obtain the wasteload allocation for the pollutant causing the water quality impairment. Permittees need to participate in the development of TMDL implementation plans since recommendations from the process may result in modifications to the stormwater management plan in order to meet the TMDL.

Additional information on Virginia's Stormwater Management program and a downloadable menu of Best Management Practices and Measurable Goals Guidance can be found at <http://www.dcr.virginia.gov/sw/stormwat.htm>.

7.4.4. Implementation Funding Sources

Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". Potential sources for implementation may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program, Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund, tax credits and landowner contributions. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support

implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

7.4.5. Attainability of Primary Contact Recreation Use

In some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. These streams may not be able to attain standards without some reduction in wildlife load.

With respect to these potential reductions in bacteria loads attributed to wildlife, Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards. However, if bacteria levels remain high and localized overabundant populations of wildlife are identified as the source, then measures to reduce such populations may be an option if undertaken in consultation with the Department of Game and Inland Fisheries (DGIF) or the United States Fish and Wildlife Service (USFWS). Additional information on DGIF's wildlife programs can be found at http://www.dgif.virginia.gov/hunting/va_game_wildlife/. While managing such overpopulations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

To address the overall issue of attainability of the primary contact criteria, Virginia proposed during its latest triennial water quality standards review a new "secondary contact" category for protecting the recreational use in state waters. On March 25, 2003, the Virginia State Water Control Board adopted criteria for "secondary contact recreation" which means "a water-based form of recreation, the practice of which has a low probability for total body immersion or ingestion of waters (examples include but are not limited to wading, boating and fishing)". These new criteria became effective on February 12, 2004 and can be found at <http://www.deq.virginia.gov/wqs/rule.html>.

In order for the new criteria to apply to a specific stream segment, the primary contact recreational use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10). This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process. Additional information can be obtained at <http://www.deq.virginia.gov/wqs/WQS03AUG.pdf>

The process to address potentially unattainable reductions based on the above is as follows: First is the development of a stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the stage 1 scenario are targeted primarily at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of nuisance populations. During the implementation of the stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in Mill Creek, Stony Creek, and the lower watershed of the North Fork of the Shenandoah River watersheds above. DEQ will re-assess water quality in the stream during and subsequent to the implementation of the stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, and no additional cost-effective and reasonable best management practices can be identified, a UAA may be initiated with the goal of re-designating the stream for secondary contact recreation.

CHAPTER 8: PUBLIC PARTICIPATION

Public participation was elicited at every stage of the TMDL development in order to receive input from stakeholders and to apprise the stakeholders of the progress made. The first public meeting for Mill Creek was May 18, 2005 at St. Andrews Episcopal Church, with 21 people in attendance. The first public meeting for North Fork of the Shenandoah River and Stony Creek was May 25, 2005 at Edinburg Town Hall, with 38 people in attendance. A Local Steering Committee was developed and met three times. The final public meeting was March 21, 2006 at the Shenandoah Co. Parks and Recreation Office in Edinburg, VA. For the final public meeting, the Friends of the North Fork Shenandoah River sent out over 4000 mailings informing watershed residents of the meeting and encouraging them to attend. The mailing also informed watershed residents of what they could do to contribute to the TMDL process. The draft TMDL report was made available to the public for comment on the DEQ website.

Appendix A: Glossary of Terms

Allocation

That portion of a receiving water's loading capacity that is attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources.

Allocation Scenario

A proposed series of point and nonpoint source allocations (loadings from different sources), which are being considered to meet a water quality planning goal.

ARA (Antibiotic Resistance Analysis)

A bacterial source tracking technique that uses the expected varying antibiotic resistance of bacteria from different sources to identify the contributors of fecal bacteria. Bacteria from humans are expected to have the highest antibiotic resistance, while domestic and wildlife animal sources are expected to have lower antibiotic resistance (Hagedorn, 2006).

Background levels

Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering and dissolution.

BASINS (Better Assessment Science Integrating Point and Nonpoint Sources)

A computer-run tool that contains an assessment and planning component that allows users to organize and display geographic information for selected watersheds. It also contains a modeling component to examine impacts of pollutant loadings from point and nonpoint sources and to characterize the overall condition of specific watersheds.

Best Management Practices (BMP)

Methods, measures, or practices that are determined to be reasonable and cost-effective means for a land owner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

Bacteria Source Tracking

A collection of scientific methods used to track sources of fecal coliform.

Calibration

The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.

Die-off (of fecal coliform)

Reduction in the fecal coliform population due to predation by other bacteria as well as by adverse environmental conditions (e.g., UV radiation, pH).

Direct nonpoint sources

Sources of pollution that are defined statutorily (by law) as nonpoint sources that are represented in the model as point source loadings due to limitations of the model. Examples include: direct deposits of fecal material to streams from livestock and wildlife.

Failing septic system

Septic systems in which drain fields have failed such that effluent (wastewater) that is supposed to percolate into the soil, now rises to the surface and ponds on the surface where it can flow over the soil surface to streams or contribute pollutants to the surface where they can be lost during storm runoff events.

Fecal coliform

A type of bacteria found in the feces of various warm-blooded animals that is used as indicator of the possible presence of pathogenic (disease causing) organisms. *E. coli* bacteria are a subset of this group found to more closely correlate with human health problems.

Geometric mean

The geometric mean is simply the n th root of the product of n values. Using the geometric mean lessens the significance of a few extreme values (extremely high or low values). In practical terms, this means that if you have just a few bad samples, their weight is lessened.

Mathematically the geometric mean, \bar{x}_g , is expressed as:

$$\bar{x}_g = \sqrt[n]{x_1 \cdot x_2 \cdot x_3 \dots x_n}$$

where n is the number of samples, and x_i is the value of sample i .

HSPF (Hydrological Simulation Program-Fortran)

A computer-based model that calculates runoff, sediment yield, and fate and transport of various pollutants to the stream. The model was developed under the direction of the U.S. Environmental Protection Agency (EPA).

Hydrology

The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.

Instantaneous or Single Sample criterion

The instantaneous criterion or instantaneous water quality standard is the value of the water quality standard that should not be exceeded at any time. For example, the Virginia instantaneous water quality standard for fecal coliform is 400 cfu/100 mL. If this value is exceeded at any time, the water body is in violation of the state water quality standard.

Load allocation (LA)

The portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background.

Margin of Safety (MOS)

A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody. The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models). The MOS may also be assigned explicitly, as was done in this study, to ensure that the water quality standard is not violated.

Model

Mathematical representation of hydrologic and water quality processes. Effects of Land use, slope, soil characteristics, and management practices are included.

Nonpoint source

Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.

Pathogen

Disease-causing agent, especially microorganisms such as bacteria, protozoa, and viruses.

Point source

Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.

Pollution

Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.

Reach

Segment of a stream or river.

Runoff

That part of rainfall or snowmelt that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

Septic system

An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives liquid and solid wastes from a residence or business and a drainfield or subsurface absorption system consisting of a series of tile or percolation lines for disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.

Simulation

The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.

Straight pipe

Delivers wastewater directly from a building, e.g., house, milking parlor, to a stream, pond, lake, or river.

Total Maximum Daily Load (TMDL)

The sum of the individual wasteload allocations (WLA's) for point sources, load allocations (LA's) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.

Urban Runoff

Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.

Validation (of a model)

Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical process under investigation.

Wasteload allocation (WLA)

The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation.

Water quality standard

Law or regulation that consists of the beneficial designated use or uses of a water body, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular water body, and an anti-degradation statement.

Watershed

A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

For more definitions, see the Virginia Cooperative Extension publications available online:

Glossary of Water-Related Terms. Publication 442-758.

<http://www.ext.vt.edu/pubs/bse/442-758/442-758.html>

and

TMDLs (Total Maximum Daily Loads) - Terms and Definitions. Publication 442-550.

<http://www.ext.vt.edu/pubs/bse/442-550/442-550.html>

**Appendix B: Sample Calculation of Cattle
(Sub-watershed 60 of the Mill Creek Watershed)**

Sample Calculation: Distribution of Cattle

(Sub-watershed 60 during January)

(Note: Due to rounding, the numbers may not add up.)

There are 637 beef cows in sub-watershed 60.

1. During January, beef cattle in sub-watershed 60 are confined 40% of the time (Table 4.5).

$$\text{Beef cattle in confinement} = 637 * 40\% = 254.8$$

2. When not confined, cattle are on pasture or in the stream.

$$\text{Beef cattle on pasture and in the stream} = 637 - 254.8 = 382.2$$

3. Four percent of beef cows in sub-watershed 60 have stream access. Hence beef cattle with stream access are calculated as:

$$\text{Beef cattle on pastures with stream access} = 382.2 * 4\% = 15.29$$

4. Beef cattle in and around the stream are calculated using the numbers in Step 3 and the number of hours cattle spend in the stream in January (Table 4.5) as:

$$\text{Beef cattle in and around streams} = 15.29 * 0.5/24 = 0.32$$

5. Number of cattle defecating in the stream is calculated by multiplying the number of cattle in and around the stream by 30% (Section 4.2.1):

$$\text{Beef cattle defecating in streams} = 0.32 * 30\% = 0.10$$

6. After calculating the number of cattle defecating in the stream, the number of cattle defecating on the pasture is calculated by subtracting the number of cattle defecating in the stream (Step 5) from the number of cattle in pasture and stream (Step 2):

$$\text{Beef cattle defecating on pasture} = 382.2 - 0.10 = 382.1$$

Now, obviously there are not fractions of cows standing and defecating in the stream. This number (0.14) represents the fraction of fecal coliform produced in one day by one cow that will be deposited in the stream.

Appendix C: Die-off of Fecal Coliform During Storage

Die-off of Fecal Coliform During Storage

The following procedure was used to calculate amount of fecal coliform produced in confinement in dairy manure applied to cropland and pasture. All calculations were performed on spreadsheet for each sub watershed with dairy operations in a watershed.

1. It was assumed based on previous producer surveys in previous TMDLs that 15% of the dairy farms had dairy manure storage for less than 30 days; 10% of the dairy farms had storage capacities of 60 days, while the remaining operations had 180-day storage capacity. Using a decay rate of 0.375 for liquid dairy manure, the die-off of fecal coliform in different storage capacities at the ends of the respective storage periods were calculated using Eq. [5.1]. Based on the fractions of different storage capacities, a weighted average die-off was calculated for all dairy manure.
2. Based on fecal coliform die-off, the surviving fraction of fecal coliform at the end of storage period was estimated to be 0.0078 in dairy manure.
3. The annual production of fecal coliform based on 'as-excreted' values was calculated for dairy manure.
4. The annual fecal coliform production from dairy manure was multiplied by the fraction of surviving fecal coliform to obtain the amount of fecal coliform that was available for land application on annual basis. For monthly application, the annual figure was multiplied by the fraction of dairy applied during that month based on the application schedule given in Table 4.7 and Table 4.9.

Appendix D: Weather Data Preparation

Weather Data Preparation

A weather data file for providing the weather data inputs into the HSPF Model was created for the period using WDMUtil. Raw data required for creating the weather data file included hourly precipitation (in.), average daily temperatures (maximum, minimum, and dew point) (°F), average daily wind speed (mi./h), total daily solar radiation (langleys), and percent sun. The primary data source for most parameters was the National Climatic Data Center's (NCDC) Cooperative Weather Station at Dale Enterprise, Rockingham Co., Virginia; data from three other NCDC stations were also used. Locations and data periods from the stations used are listed in Table D-1. Daily solar radiation data was generated using WDMUtil. The raw data required varying amounts of preprocessing prior to input into WDMUtil or within WDMUtil to obtain the following hourly values: precipitation (PREC), air temperature (ATEM), dew point temperature (DEWP), solar radiation (SOLR), wind speed (WIND), potential evapotranspiration (PEVT), potential evaporation (EVAP), and cloud cover (CLOU). The final WDM file contained the above hourly values as well as the raw data. Weather data in the variable length format were obtained from the NCDC's weather stations in Dale Enterprise, VA (Lat./Long. 38.5N/78.9W, elevation 1400 ft); Lynchburg Airport, VA (Lat./Long. 37.3N/79.2W, elevation 940 ft); and Elkins Airport, WV (Lat./Long. 38.9N/79.9W, elevation 1948 ft). While deciding on the period of record for the weather WDM file, availability of flow and water quality data was considered in addition to the availability and quality of weather data.

Table D.1. Meteorological data sources.

Type of Data	Location	Source	Recording Frequency	Period of Record	Latitude Longitude
Rainfall (in)	Dale Enterprise	NCDC	1 Hour 1 Day	1/1/73 - present 9/1/48 - present	38°10'52" 79°05'25"
Rainfall (in)	Mathias	NCDC	1 Hour 1 Day	9/1/48 - 5/1/93 9/1/48 - 1/1/01	38°52' 78°52'
Rainfall (in)	Star Tannery	NCDC	1 Hour 1 Day	1/1/48 - 9/1/05 9/1/48 - 10/1/05	38°10'52" 79°05'25"
Min Air Temp (°F)	Staunton Sewage Treatment Plant	NCDC	1 Day	8/1/48 - present	38°10'52" 79°05'25"
Max Air Temp (°F)	Staunton Sewage Treatment Plant	NCDC	1 Day	8/1/48 - present	38°10'52" 79°05'25"
Min Air Temp (°F)	Dale Enterprise	NCDC	1 Day	1/1/48 - present	38°27'19" 78°56'07"
Max Air Temp (°F)	Dale Enterprise	NCDC	1 Day	1/1/48 - present	38°27'19" 78°56'07"
Cloud Cover (%)	Lynchburg Regional Airport	NCDC	1 Day	1/1/65 - 7/31/96	37°20'15" 79°12'24"
Dew Point Temp (°F)	Elkins Airport, WV	NCDC	1 Day	1/1/48 - present	37°20'15" 79°12'24"
Wind Speed (360° and knots)	Elkins-Randolph Elkins WV	NCDC	1 Day	1/1/84 - present	38°53'07" 79°51'10"

Appendix E: HSPF Parameters that Vary by Month or Land Use

Table E.1. PWAT-PARM2 parameters varying by land use and subwatershed.

Land Use	Parameter	Sub-watershed Number										
		1	2	3	4	5	6	7	8	9	10	11
Crop	INFILT	0.165	0.178	0.178	0.17	0.178	0.178	0.178	0.178	0.153	0.178	0.178
	LSUR	500	500	500	500	500	500	500	500	500	500	500
	SLSUR	0.0647	0.1401	0.106	0.0916	0.054	0.0532	0.06	0.1441	0.0771	0.0672	0.0623
Forest	INFILT	0.16	0.178	0.178	0.167	0.178	0.178	0.178	0.178	0.129	0.178	0.178
	LSUR	242	390	500	344	500	425	333	416	308	358	240
	SLSUR	0.0983	0.1075	0.1128	0.1105	0.0914	0.0692	0.0729	0.1071	0.0923	0.0979	0.1005
HDR	INFILT	n/a	n/a	n/a	n/a	n/a	n/a	0.178	n/a	0.178	0.178	0.178
	LSUR	n/a	n/a	n/a	n/a	n/a	n/a	500	n/a	500	262	500
	SLSUR	n/a	n/a	n/a	n/a	n/a	n/a	0.0454	n/a	0.0585	0.0103	0.0559
LDR	INFILT	0.166	0.178	0.178	0.172	0.178	0.178	0.178	0.178	0.125	0.178	0.178
	LSUR	179	500	500	500	500	497	500	500	500	500	500
	SLSUR	0.0951	0.0985	0.1442	0.1001	0.046	0.0747	0.0682	0.0418	0.0804	0.0633	0.0607
Pasture	INFILT	0.172	0.178	0.178	0.168	0.178	0.178	0.178	0.178	0.147	0.178	0.178
	LSUR	329	500	500	458	500	91	287	500	285	242	337
	SLSUR	0.0707	0.0954	0.0999	0.0871	0.0732	0.059	0.0692	0.0812	0.0737	0.063	0.0649

Table E.1. PWAT-PARM2 parameters varying by land use and sub-watershed (continued).

Land Use	Parameter	Sub-watershed Number											
		12	13	14	15	16	17	18	19	20	21	22	23
Crop	INFILT	0.178	0.172	0.164	0.135	0.178	0.178	0.178	0.177	0.178	0.178	0.18	0.178
	LSUR	500	500	500	500	500	500	482	500	500	500	500	500
	SLSUR	0.0824	0.0738	0.0722	0.0914	0.0744	0.0725	0.0884	0.0699	0.0846	0.095	0.1249	0.1504
Forest	INFILT	0.178	0.171	0.147	0.149	0.178	0.178	0.178	0.165	0.178	0.178	0.245	0.178
	LSUR	201	327	188	319	456	246	212	445	370	380	318	500
	SLSUR	0.1278	0.0795	0.1347	0.0958	0.0752	0.1132	0.1407	0.0926	0.0937	0.1143	0.2049	0.1366
HDR	INFILT	0.178	n/a	n/a	0.103	0.178	0.178	0.178	0.163	0.178	0.178	0.178	0.178
	LSUR	500	n/a	n/a	390	500	500	474	500	500	149	500	500
	SLSUR	0.0963	n/a	n/a	0.0905	0.0695	0.0799	0.1116	0.0728	0.0955	0.0893	0.0832	0.0969
LDR	INFILT	0.178	0.139	0.096	0.117	0.178	0.178	0.178	0.167	0.178	0.178	0.184	0.178
	LSUR	500	500	118	500	500	260	500	500	500	500	500	500
	SLSUR	0.1401	0.0543	0.1273	0.096	0.0886	0.0824	0.1163	0.0809	0.0677	0.0853	0.121	0.1141
Pasture	INFILT	0.178	0.177	0.15	0.137	0.178	0.178	0.163	0.178	0.178	0.178	0.193	0.178
	LSUR	114	351	297	246	231	214	129	500	148	291	374	500
	SLSUR	0.0831	0.0777	0.0826	0.0958	0.0709	0.0886	0.0947	0.0772	0.0888	0.0886	0.1369	0.1189

Table E.2. MON-INTERCEP (monthly CEPSC) - Monthly Interception Storage.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Forest	0.1	0.1	0.13	0.16	0.18	0.3	0.3	0.3	0.19	0.14	0.12	0.1
HDR	0.09	0.09	0.09	0.09	0.09	0.11	0.11	0.11	0.09	0.09	0.09	0.09
LDR	0.09	0.09	0.09	0.09	0.09	0.11	0.11	0.11	0.09	0.09	0.09	0.09
Pasture	0.08	0.09	0.13	0.16	0.18	0.2	0.2	0.2	0.19	0.14	0.1	0.08
Crop	0.06	0.07	0.1	0.18	0.21	0.26	0.26	0.23	0.2	0.18	0.08	0.06

Table E.3. MON-UZSN - Monthly Upper Zone Nominal Storage.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Forest	0.9	0.9	0.9	0.9	1	1	1	1	1	0.95	0.9	0.9
HDR	0.8	0.8	0.8	0.8	0.9	1	1	1	0.9	0.8	0.8	0.8
LDR	0.8	0.8	0.8	0.8	0.9	1	1	1	0.9	0.8	0.8	0.8
Pasture	0.8	0.8	0.8	0.8	0.9	1	1	1	1	0.8	0.8	0.8
Crop	0.35	0.35	0.35	0.4	0.5	0.9	0.9	0.9	0.8	0.6	0.4	0.35

Table E.4. MON-LZETP - Monthly Lower Zone Evapotranspiration Parameter.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Forest	0.35	0.35	0.45	0.5	0.55	0.75	0.75	0.65	0.6	0.5	0.45	0.35
HDR	0.25	0.25	0.27	0.27	0.3	0.3	0.3	0.3	0.27	0.27	0.25	0.25
LDR	0.25	0.25	0.3	0.3	0.35	0.35	0.35	0.3	0.3	0.3	0.25	0.25
Pasture	0.25	0.35	0.45	0.5	0.55	0.75	0.75	0.65	0.6	0.5	0.4	0.25
Crop	0.25	0.35	0.45	0.5	0.55	0.75	0.75	0.65	0.6	0.5	0.4	0.25

Table E-1. Mill Creek: Monthly nonpoint fecal coliform loadings in sub-watershed MC-56.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	5	9,205	0	0	31	18,124	0
Feb.	82	9,960	0	0	28	16,517	0
Mar.	392	18,950	0	0	24	18,124	0
Apr.	314	18,625	0	0	23	17,540	0
May.	82	19,030	0	0	24	18,124	0
Jun.	4	18,882	0	0	23	17,540	0
Jul.	5	19,996	0	0	24	18,124	0
Aug.	5	20,488	0	0	24	18,124	0
Sep.	4	20,555	0	0	30	17,540	0
Oct.	123	13,471	0	0	31	18,124	0
Nov.	122	13,648	0	0	30	17,540	0
Dec.	5	8,836	0	0	31	18,124	0
Total	1,143	191,645	0	0	323	213,547	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-2. Mill Creek: Monthly nonpoint fecal coliform loadings in sub-watershed MC-57.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	4	24,310	0	0	49	30,263	0
Feb.	98	29,470	0	0	45	27,578	0
Mar.	474	66,471	0	0	38	30,263	0
Apr.	380	61,891	0	0	37	29,287	0
May.	98	51,892	0	0	38	30,263	0
Jun.	4	51,412	0	0	37	29,287	0
Jul.	4	54,121	0	0	38	30,263	0
Aug.	4	55,256	0	0	38	30,263	0
Sep.	4	58,961	0	0	48	29,287	0
Oct.	104	42,759	0	0	49	30,263	0
Nov.	147	43,030	0	0	48	29,287	0
Dec.	4	23,458	0	0	49	30,263	0
Total	1,323	563,031	0	0	513	356,565	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-3. Mill Creek: Monthly nonpoint fecal coliform loadings in sub-watershed MC-58.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	2	5,448	0	0	20	3,937	0
Feb.	55	5,769	0	0	18	3,587	0
Mar.	269	10,587	0	0	16	3,937	0
Apr.	216	10,521	0	0	16	3,810	0
May.	56	11,141	0	0	16	3,937	0
Jun.	2	11,040	0	0	16	3,810	0
Jul.	2	11,699	0	0	16	3,937	0
Aug.	2	11,991	0	0	16	3,937	0
Sep.	2	11,917	0	0	19	3,810	0
Oct.	84	7,720	0	0	20	3,937	0
Nov.	83	7,827	0	0	19	3,810	0
Dec.	2	5,229	0	0	20	3,937	0
Total	777	110,889	0	0	214	46,383	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-4. Mill Creek: Monthly nonpoint fecal coliform loadings in sub-watershed MC-59.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	5	21,540	0	0	208	30,838	0
Feb.	253	24,612	0	0	189	28,103	0
Mar.	1,247	50,850	0	0	177	30,838	0
Apr.	998	48,772	0	0	171	29,844	0
May.	254	45,776	0	0	177	30,838	0
Jun.	5	45,335	0	0	171	29,844	0
Jul.	5	47,932	0	0	177	30,838	0
Aug.	5	49,078	0	0	177	30,838	0
Sep.	5	50,644	0	0	201	29,844	0
Oct.	383	34,112	0	0	208	30,838	0
Nov.	383	34,534	0	0	201	29,844	0
Dec.	5	20,676	0	0	208	30,838	0
Total	3,551	473,860	0	0	2,265	363,347	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-5. Mill Creek: Monthly nonpoint fecal coliform loadings in sub-watershed MC-60.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	11	40,808	0	0	134	48,173	0
Feb.	256	44,137	0	0	122	43,900	0
Mar.	1,244	83,562	0	0	111	48,173	0
Apr.	997	81,852	0	0	108	46,619	0
May.	257	82,804	0	0	111	48,173	0
Jun.	10	82,121	0	0	108	46,619	0
Jul.	11	86,906	0	0	111	48,173	0
Aug.	11	88,996	0	0	111	48,173	0
Sep.	10	89,498	0	0	129	46,619	0
Oct.	327	59,469	0	0	134	48,173	0
Nov.	386	60,168	0	0	129	46,619	0
Dec.	11	39,238	0	0	134	48,173	0
Total	3,529	839,558	0	0	1,441	567,590	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-6. Mill Creek: Monthly nonpoint fecal coliform loadings in sub-watershed MC-61.

Month	Fecal Coliform loadings (x10¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential¹	
Jan.	3	15,223	0	0	155	14,580	0
Feb.	122	16,114	0	0	141	13,287	0
Mar.	597	29,543	0	0	136	14,580	0
Apr.	478	29,357	0	0	132	14,110	0
May.	122	31,087	0	0	136	14,580	0
Jun.	3	30,805	0	0	132	14,110	0
Jul.	3	32,643	0	0	136	14,580	0
Aug.	3	33,454	0	0	136	14,580	0
Sep.	3	33,248	0	0	150	14,110	0
Oct.	184	21,554	0	0	155	14,580	0
Nov.	184	21,850	0	0	150	14,110	0
Dec.	3	14,612	0	0	155	14,580	0
Total	1,705	309,490	0	0	1,712	171,786	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-7. Mill Creek: Monthly nonpoint fecal coliform loadings in sub-watershed MC-62.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	1	3,566	0	0	361	12,669	0
Feb.	57	4,628	0	0	329	11,545	0
Mar.	278	11,181	0	0	324	12,669	0
Apr.	223	10,281	0	0	313	12,260	0
May.	57	8,118	0	0	324	12,669	0
Jun.	1	8,033	0	0	313	12,260	0
Jul.	1	8,461	0	0	324	12,669	0
Aug.	1	8,650	0	0	324	12,669	0
Sep.	1	9,476	0	0	349	12,260	0
Oct.	86	6,750	0	0	361	12,669	0
Nov.	86	6,821	0	0	349	12,260	0
Dec.	1	3,423	0	0	361	12,669	0
Total	793	89,387	0	0	4,033	149,267	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-8. Mill Creek: Monthly nonpoint fecal coliform loadings in sub-watershed MC-63.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	1	5,993	0	0	298	12,211	0
Feb.	9	6,637	0	0	271	11,128	0
Mar.	41	13,092	0	0	269	12,211	0
Apr.	33	12,722	0	0	260	11,817	0
May.	9	12,519	0	0	269	12,211	0
Jun.	1	12,355	0	0	260	11,817	0
Jul.	1	13,075	0	0	269	12,211	0
Aug.	1	13,393	0	0	269	12,211	0
Sep.	1	13,661	0	0	288	11,817	0
Oct.	13	9,064	0	0	298	12,211	0
Nov.	13	9,186	0	0	288	11,817	0
Dec.	1	5,752	0	0	298	12,211	0
Total	123	127,449	0	0	3,334	143,877	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-9. Mill Creek: Monthly nonpoint fecal coliform loadings in sub-watershed MC-64.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	0	663	0	0	268	6,421	0
Feb.	2	863	0	0	245	5,851	0
Mar.	12	2,091	0	0	235	6,421	0
Apr.	10	1,921	0	0	227	6,214	0
May.	2	1,513	0	0	235	6,421	0
Jun.	0	1,480	0	0	227	6,214	0
Jul.	0	1,559	0	0	235	6,421	0
Aug.	0	1,595	0	0	235	6,421	0
Sep.	0	1,768	0	0	260	6,214	0
Oct.	4	1,258	0	0	268	6,421	0
Nov.	4	1,273	0	0	260	6,214	0
Dec.	0	636	0	0	268	6,421	0
Total	35	16,621	0	0	2,965	75,653	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-10. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-29.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	15	7,947	0	0	301	502,275	0
Feb.	518	8,849	0	0	275	457,718	0
Mar.	2,534	17,000	0	0	220	502,275	0
Apr.	2,030	15,664	0	0	213	486,072	0
May.	519	12,796	0	0	220	502,275	0
Jun.	15	12,566	0	0	213	486,072	0
Jul.	15	13,119	0	0	220	502,275	0
Aug.	15	13,290	0	0	220	502,275	0
Sep.	15	14,222	0	0	292	486,072	0
Oct.	782	11,912	0	0	301	502,275	0
Nov.	781	11,811	0	0	292	486,072	0
Dec.	15	7,818	0	0	301	502,275	0
Total	7,255	146,994	0	0	3,066	5,917,932	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-11. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-30.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	0	1,360	0	0	39	12,776	0
Feb.	3	1,488	0	0	36	11,642	0
Mar.	12	2,765	0	0	30	12,776	0
Apr.	10	2,605	0	0	29	12,364	0
May.	3	2,317	0	0	30	12,776	0
Jun.	0	2,287	0	0	29	12,364	0
Jul.	0	2,401	0	0	30	12,776	0
Aug.	0	2,443	0	0	30	12,776	0
Sep.	0	2,543	0	0	38	12,364	0
Oct.	4	1,954	0	0	39	12,776	0
Nov.	4	1,951	0	0	38	12,364	0
Dec.	0	1,329	0	0	39	12,776	0
Total	39	25,442	0	0	405	150,527	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-12. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-31.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	1	976	0	0	77	11,138	0
Feb.	17	1,059	0	0	70	10,150	0
Mar.	82	1,937	0	0	55	11,138	0
Apr.	66	1,827	0	0	53	10,779	0
May.	17	1,633	0	0	55	11,138	0
Jun.	1	1,607	0	0	53	10,779	0
Jul.	1	1,687	0	0	55	11,138	0
Aug.	1	1,716	0	0	55	11,138	0
Sep.	1	1,786	0	0	74	10,779	0
Oct.	26	1,382	0	0	77	11,138	0
Nov.	26	1,379	0	0	74	10,779	0
Dec.	1	954	0	0	77	11,138	0
Total	242	17,942	0	0	774	131,232	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-13. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-32.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	16	9,928	0	0	416	221,964	0
Feb.	129	10,837	0	0	379	202,274	0
Mar.	591	20,032	0	0	305	221,964	0
Apr.	476	18,871	0	0	295	214,804	0
May.	131	16,791	0	0	305	221,964	0
Jun.	15	16,532	0	0	295	214,804	0
Jul.	16	17,353	0	0	305	221,964	0
Aug.	16	17,655	0	0	305	221,964	0
Sep.	15	18,412	0	0	403	214,804	0
Oct.	191	14,193	0	0	416	221,964	0
Nov.	190	14,167	0	0	403	214,804	0
Dec.	16	9,700	0	0	416	221,964	0
Total	1,800	184,473	0	0	4,242	2,615,236	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-14. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-34.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	16	16,306	0	0	464	163,913	0
Feb.	239	16,924	0	0	423	149,373	0
Mar.	1,138	28,907	0	0	352	163,913	0
Apr.	913	27,389	0	0	341	158,626	0
May.	241	25,199	0	0	352	163,913	0
Jun.	16	24,731	0	0	341	158,626	0
Jul.	16	25,870	0	0	352	163,913	0
Aug.	16	26,221	0	0	352	163,913	0
Sep.	16	26,886	0	0	449	158,626	0
Oct.	349	22,166	0	0	464	163,913	0
Nov.	357	21,951	0	0	449	158,626	0
Dec.	16	16,042	0	0	464	163,913	0
Total	3,336	278,593	0	0	4,803	1,931,270	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-15. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-37.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	3	6,100	0	0	580	62,278	0
Feb.	84	8,290	0	0	529	56,753	0
Mar.	407	20,460	0	0	433	62,278	0
Apr.	326	18,111	0	0	419	60,269	0
May.	84	11,927	0	0	433	62,278	0
Jun.	3	11,749	0	0	419	60,269	0
Jul.	3	12,251	0	0	433	62,278	0
Aug.	3	12,435	0	0	433	62,278	0
Sep.	3	14,554	0	0	561	60,269	0
Oct.	126	11,978	0	0	580	62,278	0
Nov.	126	11,964	0	0	561	60,269	0
Dec.	3	5,961	0	0	580	62,278	0
Total	1,173	145,780	0	0	5,963	733,773	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-16. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-38.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	7	3,116	0	0	122	25,901	0
Feb.	246	4,983	0	0	111	23,603	0
Mar.	1,208	14,193	0	0	92	25,901	0
Apr.	967	12,245	0	0	89	25,065	0
May.	247	6,842	0	0	92	25,901	0
Jun.	7	6,768	0	0	89	25,065	0
Jul.	7	7,025	0	0	92	25,901	0
Aug.	7	7,119	0	0	92	25,901	0
Sep.	7	8,932	0	0	118	25,065	0
Oct.	372	7,617	0	0	122	25,901	0
Nov.	372	7,608	0	0	118	25,065	0
Dec.	7	3,045	0	0	122	25,901	0
Total	3,453	89,494	0	0	1,257	305,170	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-17. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-39.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	4	3,277	0	0	93	38,077	0
Feb.	60	3,568	0	0	85	34,699	0
Mar.	286	6,564	0	0	73	38,077	0
Apr.	229	6,188	0	0	70	36,848	0
May.	60	5,523	0	0	73	38,077	0
Jun.	4	5,448	0	0	70	36,848	0
Jul.	4	5,719	0	0	73	38,077	0
Aug.	4	5,818	0	0	73	38,077	0
Sep.	4	6,049	0	0	90	36,848	0
Oct.	90	4,666	0	0	93	38,077	0
Nov.	90	4,656	0	0	90	36,848	0
Dec.	4	3,203	0	0	93	38,077	0
Total	838	60,680	0	0	974	448,627	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-18. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-40.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	6	8,036	0	0	442	39,972	0
Feb.	50	10,076	0	0	402	36,426	0
Mar.	228	23,676	0	0	390	39,972	0
Apr.	183	21,082	0	0	377	38,682	0
May.	50	14,561	0	0	390	39,972	0
Jun.	6	14,313	0	0	377	38,682	0
Jul.	6	14,834	0	0	390	39,972	0
Aug.	6	14,993	0	0	390	39,972	0
Sep.	6	17,099	0	0	427	38,682	0
Oct.	40	15,177	0	0	442	39,972	0
Nov.	73	15,028	0	0	427	38,682	0
Dec.	6	7,925	0	0	442	39,972	0
Total	661	176,799	0	0	4,895	470,957	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-19. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-41.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	0	363	0	0	731	29,267	0
Feb.	3	400	0	0	666	26,671	0
Mar.	16	756	0	0	620	29,267	0
Apr.	13	712	0	0	600	28,323	0
May.	3	631	0	0	620	29,267	0
Jun.	0	623	0	0	600	28,323	0
Jul.	0	654	0	0	620	29,267	0
Aug.	0	666	0	0	620	29,267	0
Sep.	0	695	0	0	708	28,323	0
Oct.	5	529	0	0	731	29,267	0
Nov.	5	529	0	0	708	28,323	0
Dec.	0	354	0	0	731	29,267	0
Total	47	6,911	0	0	7,955	344,831	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-20. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-42.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	0	491	0	0	356	6,141	0
Feb.	1	535	0	0	324	5,596	0
Mar.	6	983	0	0	295	6,141	0
Apr.	5	926	0	0	285	5,943	0
May.	1	825	0	0	295	6,141	0
Jun.	0	809	0	0	285	5,943	0
Jul.	0	849	0	0	295	6,141	0
Aug.	0	864	0	0	295	6,141	0
Sep.	0	903	0	0	344	5,943	0
Oct.	2	698	0	0	356	6,141	0
Nov.	2	697	0	0	344	5,943	0
Dec.	0	480	0	0	356	6,141	0
Total	19	9,060	0	0	3,829	72,352	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-21. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-43.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	4	3,316	0	0	634	36,454	0
Feb.	59	4,180	0	0	578	33,220	0
Mar.	284	9,497	0	0	509	36,454	0
Apr.	227	8,550	0	0	493	35,278	0
May.	60	6,177	0	0	509	36,454	0
Jun.	3	6,098	0	0	493	35,278	0
Jul.	4	6,373	0	0	509	36,454	0
Aug.	4	6,475	0	0	509	36,454	0
Sep.	3	7,280	0	0	614	35,278	0
Oct.	89	5,864	0	0	634	36,454	0
Nov.	89	5,855	0	0	614	35,278	0
Dec.	4	3,240	0	0	634	36,454	0
Total	829	72,906	0	0	6,730	429,507	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-22. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-46.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	Loafing Lot
Jan.	0	203	0	0	516	21,991	0
Feb.	6	227	0	0	470	20,040	0
Mar.	30	438	0	0	428	21,991	0
Apr.	24	412	0	0	415	21,281	0
May.	6	363	0	0	428	21,991	0
Jun.	0	358	0	0	415	21,281	0
Jul.	0	376	0	0	428	21,991	0
Aug.	0	383	0	0	428	21,991	0
Sep.	0	402	0	0	499	21,281	0
Oct.	9	302	0	0	516	21,991	0
Nov.	9	303	0	0	499	21,281	0
Dec.	0	198	0	0	516	21,991	0
Total	88	3,965	0	0	5,560	259,101	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-23. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-47.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	0	832	0	0	181	1,800	0
Feb.	2	909	0	0	165	1,641	0
Mar.	7	1,681	0	0	144	1,800	0
Apr.	6	1,583	0	0	140	1,742	0
May.	2	1,406	0	0	144	1,800	0
Jun.	0	1,378	0	0	140	1,742	0
Jul.	0	1,447	0	0	144	1,800	0
Aug.	0	1,472	0	0	144	1,800	0
Sep.	0	1,542	0	0	176	1,742	0
Oct.	2	1,190	0	0	181	1,800	0
Nov.	2	1,188	0	0	176	1,742	0
Dec.	0	813	0	0	181	1,800	0
Total	22	15,440	0	0	1,916	21,214	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-24. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-48.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	2	981	0	0	328	12,424	0
Feb.	27	1,068	0	0	299	11,322	0
Mar.	130	1,966	0	0	277	12,424	0
Apr.	104	1,852	0	0	268	12,023	0
May.	27	1,649	0	0	277	12,424	0
Jun.	1	1,620	0	0	268	12,023	0
Jul.	2	1,700	0	0	277	12,424	0
Aug.	2	1,729	0	0	277	12,424	0
Sep.	1	1,807	0	0	317	12,023	0
Oct.	41	1,396	0	0	328	12,424	0
Nov.	41	1,394	0	0	317	12,023	0
Dec.	2	959	0	0	328	12,424	0
Total	380	18,121	0	0	3,562	146,381	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-25. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-50.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	2	1,983	0	0	405	18,763	0
Feb.	21	2,161	0	0	369	17,098	0
Mar.	98	3,987	0	0	344	18,763	0
Apr.	79	3,757	0	0	333	18,157	0
May.	21	3,349	0	0	344	18,763	0
Jun.	2	3,295	0	0	333	18,157	0
Jul.	2	3,459	0	0	344	18,763	0
Aug.	2	3,519	0	0	344	18,763	0
Sep.	2	3,670	0	0	392	18,157	0
Oct.	31	2,829	0	0	405	18,763	0
Nov.	31	2,824	0	0	392	18,157	0
Dec.	2	1,937	0	0	405	18,763	0
Total	291	36,768	0	0	4,410	221,066	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-26. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-51.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	1	579	0	0	910	3,344	0
Feb.	2	618	0	0	830	3,048	0
Mar.	5	1,090	0	0	866	3,344	0
Apr.	4	1,029	0	0	838	3,237	0
May.	2	925	0	0	866	3,344	0
Jun.	1	905	0	0	838	3,237	0
Jul.	1	949	0	0	866	3,344	0
Aug.	1	964	0	0	866	3,344	0
Sep.	1	1,005	0	0	881	3,237	0
Oct.	2	794	0	0	910	3,344	0
Nov.	2	791	0	0	881	3,237	0
Dec.	1	568	0	0	910	3,344	0
Total	25	10,218	0	0	10,461	39,405	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-27. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-52.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	0	469	0	0	224	4,568	0
Feb.	10	735	0	0	204	4,163	0
Mar.	51	2,061	0	0	187	4,568	0
Apr.	41	1,781	0	0	181	4,421	0
May.	10	1,005	0	0	187	4,568	0
Jun.	0	992	0	0	181	4,421	0
Jul.	0	1,030	0	0	187	4,568	0
Aug.	0	1,044	0	0	187	4,568	0
Sep.	0	1,305	0	0	217	4,421	0
Oct.	16	1,116	0	0	224	4,568	0
Nov.	16	1,114	0	0	217	4,421	0
Dec.	0	458	0	0	224	4,568	0
Total	145	13,110	0	0	2,421	53,821	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-28. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-54.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	1	310	0	0	346	10,350	0
Feb.	33	487	0	0	315	9,431	0
Mar.	159	1,364	0	0	292	10,350	0
Apr.	127	1,177	0	0	282	10,016	0
May.	33	662	0	0	292	10,350	0
Jun.	1	652	0	0	282	10,016	0
Jul.	1	676	0	0	292	10,350	0
Aug.	1	685	0	0	292	10,350	0
Sep.	1	860	0	0	335	10,016	0
Oct.	49	738	0	0	346	10,350	0
Nov.	49	737	0	0	335	10,016	0
Dec.	1	304	0	0	346	10,350	0
Total	455	8,653	0	0	3,752	121,941	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-29. Stony Creek: Monthly nonpoint fecal coliform loadings in sub-watershed SC-55.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	2	1,293	0	0	809	76,951	0
Feb.	49	1,923	0	0	737	70,125	0
Mar.	239	5,165	0	0	697	76,951	0
Apr.	192	4,498	0	0	675	74,469	0
May.	49	2,678	0	0	697	76,951	0
Jun.	1	2,636	0	0	675	74,469	0
Jul.	2	2,740	0	0	697	76,951	0
Aug.	2	2,778	0	0	697	76,951	0
Sep.	1	3,401	0	0	783	74,469	0
Oct.	74	2,869	0	0	809	76,951	0
Nov.	74	2,865	0	0	783	74,469	0
Dec.	2	1,264	0	0	809	76,951	0
Total	686	34,110	0	0	8,870	906,656	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-30. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-1.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	14	31,539	0	0	678	5,398	0
Feb.	515	33,217	0	0	618	4,919	0
Mar.	2,523	60,096	0	0	522	5,398	0
Apr.	2,021	59,657	0	0	505	5,224	0
May.	516	63,055	0	0	522	5,398	0
Jun.	14	62,380	0	0	505	5,224	0
Jul.	14	66,068	0	0	522	5,398	0
Aug.	14	67,678	0	0	522	5,398	0
Sep.	14	67,329	0	0	656	5,224	0
Oct.	778	44,150	0	0	678	5,398	0
Nov.	777	44,704	0	0	656	5,224	0
Dec.	14	30,325	0	0	678	5,398	0
Total	7,213	630,197	0	0	7,059	63,598	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-31. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-3.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	7	81,905	0	0	2,129	3,309	0
Feb.	508	85,849	0	0	1,941	3,016	0
Mar.	2,514	156,689	0	0	1,631	3,309	0
Apr.	2,013	155,855	0	0	1,578	3,203	0
May.	508	164,282	0	0	1,631	3,309	0
Jun.	7	162,251	0	0	1,578	3,203	0
Jul.	7	171,653	0	0	1,631	3,309	0
Aug.	7	175,654	0	0	1,631	3,309	0
Sep.	7	174,744	0	0	2,061	3,203	0
Oct.	725	117,382	0	0	2,129	3,309	0
Nov.	770	117,958	0	0	2,061	3,203	0
Dec.	7	78,885	0	0	2,129	3,309	0
Total	7,079	1,643,108	0	0	22,131	38,992	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-32. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-4.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	12	58,646	0	0	908	2,883	0
Feb.	1,029	62,632	0	0	827	2,628	0
Mar.	5,104	116,079	0	0	709	2,883	0
Apr.	4,085	114,405	0	0	686	2,790	0
May.	1,030	118,142	0	0	709	2,883	0
Jun.	12	116,968	0	0	686	2,790	0
Jul.	12	123,832	0	0	709	2,883	0
Aug.	12	126,829	0	0	709	2,883	0
Sep.	12	126,956	0	0	878	2,790	0
Oct.	1,562	83,839	0	0	908	2,883	0
Nov.	1,561	84,861	0	0	878	2,790	0
Dec.	12	56,389	0	0	908	2,883	0
Total	14,444	1,189,578	0	0	9,513	33,972	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-33. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-5.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	4	26,960	0	0	833	1,294	0
Feb.	234	28,388	0	0	759	1,179	0
Mar.	1,158	51,328	0	0	630	1,294	0
Apr.	927	50,949	0	0	610	1,252	0
May.	235	53,844	0	0	630	1,294	0
Jun.	4	53,241	0	0	610	1,252	0
Jul.	4	56,387	0	0	630	1,294	0
Aug.	4	57,761	0	0	630	1,294	0
Sep.	4	57,489	0	0	806	1,252	0
Oct.	355	37,718	0	0	833	1,294	0
Nov.	355	38,192	0	0	806	1,252	0
Dec.	4	25,923	0	0	833	1,294	0
Total	3,287	538,181	0	0	8,609	15,242	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-34. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-7.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	11	59,292	0	0	828	3,625	0
Feb.	946	63,394	0	0	754	3,303	0
Mar.	4,689	117,729	0	0	662	3,625	0
Apr.	3,753	115,975	0	0	641	3,508	0
May.	946	119,560	0	0	662	3,625	0
Jun.	10	118,456	0	0	641	3,508	0
Jul.	11	125,403	0	0	662	3,625	0
Aug.	11	128,437	0	0	662	3,625	0
Sep.	10	128,546	0	0	801	3,508	0
Oct.	1,434	84,922	0	0	828	3,625	0
Nov.	1,434	85,948	0	0	801	3,508	0
Dec.	11	57,010	0	0	828	3,625	0
Total	13,267	1,204,672	0	0	8,768	42,711	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-35. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-8.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	18	43,515	0	0	441	4,868	0
Feb.	646	45,331	0	0	402	4,436	0
Mar.	3,165	83,133	0	0	337	4,868	0
Apr.	2,535	82,940	0	0	326	4,711	0
May.	647	87,527	0	0	337	4,868	0
Jun.	17	86,559	0	0	326	4,711	0
Jul.	18	91,490	0	0	337	4,868	0
Aug.	18	93,538	0	0	337	4,868	0
Sep.	17	92,709	0	0	427	4,711	0
Oct.	930	63,507	0	0	441	4,868	0
Nov.	975	63,387	0	0	427	4,711	0
Dec.	18	41,975	0	0	441	4,868	0
Total	9,003	875,612	0	0	4,578	57,355	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-36. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-9.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	15	23,747	0	0	874	2,368	0
Feb.	280	25,763	0	0	797	2,158	0
Mar.	1,349	49,005	0	0	664	2,368	0
Apr.	1,082	47,915	0	0	643	2,292	0
May.	282	48,198	0	0	664	2,368	0
Jun.	14	47,655	0	0	643	2,292	0
Jul.	15	50,428	0	0	664	2,368	0
Aug.	15	51,638	0	0	664	2,368	0
Sep.	14	52,166	0	0	846	2,292	0
Oct.	421	34,740	0	0	874	2,368	0
Nov.	420	35,159	0	0	846	2,292	0
Dec.	15	22,833	0	0	874	2,368	0
Total	3,921	489,248	0	0	9,055	27,900	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-37. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-10.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	28	77,042	0	0	1,096	3,379	0
Feb.	2,258	80,795	0	0	999	3,079	0
Mar.	11,193	149,583	0	0	865	3,379	0
Apr.	8,959	148,560	0	0	838	3,270	0
May.	2,261	155,070	0	0	865	3,379	0
Jun.	27	153,273	0	0	838	3,270	0
Jul.	28	161,987	0	0	865	3,379	0
Aug.	28	165,613	0	0	865	3,379	0
Sep.	27	164,796	0	0	1,061	3,270	0
Oct.	3,358	113,052	0	0	1,096	3,379	0
Nov.	3,425	113,020	0	0	1,061	3,270	0
Dec.	28	74,313	0	0	1,096	3,379	0
Total	31,620	1,557,105	0	0	11,545	39,807	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-38. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-12.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	52	91,048	0	0	1,626	5,628	0
Feb.	1,426	97,347	0	0	1,482	5,129	0
Mar.	6,945	180,785	0	0	1,321	5,628	0
Apr.	5,565	178,090	0	0	1,278	5,446	0
May.	1,430	183,588	0	0	1,321	5,628	0
Jun.	50	181,936	0	0	1,278	5,446	0
Jul.	52	192,605	0	0	1,321	5,628	0
Aug.	52	197,264	0	0	1,321	5,628	0
Sep.	50	197,389	0	0	1,574	5,446	0
Oct.	2,149	130,409	0	0	1,626	5,628	0
Nov.	2,148	131,980	0	0	1,574	5,446	0
Dec.	52	87,545	0	0	1,626	5,628	0
Total	19,970	1,849,986	0	0	17,347	66,310	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-39. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-14.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	Loafing Lot
Jan.	11	3,424	0	0	77	261	0
Feb.	336	3,606	0	0	70	238	0
Mar.	1,642	6,524	0	0	54	261	0
Apr.	1,316	6,476	0	0	53	253	0
May.	337	6,844	0	0	54	261	0
Jun.	11	6,768	0	0	53	253	0
Jul.	11	7,168	0	0	54	261	0
Aug.	11	7,342	0	0	54	261	0
Sep.	11	7,308	0	0	74	253	0
Oct.	507	4,793	0	0	77	261	0
Nov.	507	4,853	0	0	74	253	0
Dec.	11	3,292	0	0	77	261	0
Total	4,711	68,398	0	0	770	3,081	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-40. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-16.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	58	77,867	0	0	588	1,824	0
Feb.	2,200	84,541	0	0	536	1,662	0
Mar.	10,796	169,232	0	0	439	1,824	0
Apr.	8,646	165,635	0	0	425	1,765	0
May.	2,205	161,959	0	0	439	1,824	0
Jun.	56	160,019	0	0	425	1,765	0
Jul.	58	168,702	0	0	439	1,824	0
Aug.	58	172,186	0	0	439	1,824	0
Sep.	56	174,406	0	0	569	1,765	0
Oct.	3,177	125,022	0	0	588	1,824	0
Nov.	3,324	123,602	0	0	569	1,765	0
Dec.	58	75,247	0	0	588	1,824	0
Total	30,691	1,658,418	0	0	6,046	21,491	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-41. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-17.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	30	64,438	0	0	288	3,190	0
Feb.	1,689	71,658	0	0	263	2,907	0
Mar.	8,337	141,319	0	0	229	3,190	0
Apr.	6,675	136,292	0	0	222	3,087	0
May.	1,691	130,765	0	0	229	3,190	0
Jun.	29	129,679	0	0	222	3,087	0
Jul.	30	137,044	0	0	229	3,190	0
Aug.	30	140,228	0	0	229	3,190	0
Sep.	29	143,239	0	0	279	3,087	0
Oct.	2,558	97,570	0	0	288	3,190	0
Nov.	2,557	98,557	0	0	279	3,087	0
Dec.	30	62,047	0	0	288	3,190	0
Total	23,683	1,352,837	0	0	3,045	37,589	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-42. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-18.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	33	94,349	0	0	566	4,321	0
Feb.	2,109	122,170	0	0	516	3,938	0
Mar.	10,426	298,510	0	0	423	4,321	0
Apr.	8,346	273,647	0	0	410	4,182	0
May.	2,112	210,422	0	0	423	4,321	0
Jun.	32	208,188	0	0	410	4,182	0
Jul.	33	218,599	0	0	423	4,321	0
Aug.	33	222,885	0	0	423	4,321	0
Sep.	32	245,485	0	0	548	4,182	0
Oct.	3,106	184,433	0	0	566	4,321	0
Nov.	3,195	184,155	0	0	548	4,182	0
Dec.	33	91,122	0	0	566	4,321	0
Total	29,489	2,353,963	0	0	5,824	50,915	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-43. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-19.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	27	49,796	0	0	234	1,794	0
Feb.	945	54,203	0	0	213	1,634	0
Mar.	4,632	103,335	0	0	189	1,794	0
Apr.	3,710	100,612	0	0	183	1,736	0
May.	948	99,826	0	0	189	1,794	0
Jun.	26	99,007	0	0	183	1,736	0
Jul.	27	104,695	0	0	189	1,794	0
Aug.	27	107,152	0	0	189	1,794	0
Sep.	26	108,292	0	0	226	1,736	0
Oct.	1,428	73,050	0	0	234	1,794	0
Nov.	1,427	73,807	0	0	226	1,736	0
Dec.	27	47,951	0	0	234	1,794	0
Total	13,248	1,021,726	0	0	2,490	21,132	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-44. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-20.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	4	32,634	0	0	265	874	0
Feb.	198	36,172	0	0	241	797	0
Mar.	972	73,662	0	0	192	874	0
Apr.	778	71,121	0	0	186	846	0
May.	198	67,026	0	0	192	874	0
Jun.	4	66,174	0	0	186	846	0
Jul.	4	69,725	0	0	192	874	0
Aug.	4	71,154	0	0	192	874	0
Sep.	4	73,001	0	0	256	846	0
Oct.	254	52,723	0	0	265	874	0
Nov.	299	52,363	0	0	256	846	0
Dec.	4	31,558	0	0	265	874	0
Total	2,724	697,311	0	0	2,688	10,300	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-45. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-21.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	2	9,613	0	0	107	322	0
Feb.	71	10,244	0	0	97	293	0
Mar.	348	21,573	0	0	77	322	0
Apr.	279	21,186	0	0	75	312	0
May.	71	20,132	0	0	77	322	0
Jun.	2	19,769	0	0	75	312	0
Jul.	2	20,707	0	0	77	322	0
Aug.	2	21,009	0	0	77	322	0
Sep.	2	21,330	0	0	103	312	0
Oct.	63	17,242	0	0	107	322	0
Nov.	107	16,526	0	0	103	312	0
Dec.	2	9,387	0	0	107	322	0
Total	954	208,718	0	0	1,082	3,793	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-46. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-22.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	Loafing Lot
Jan.	10	15,595	0	0	84	499	0
Feb.	865	16,662	0	0	76	455	0
Mar.	4,290	30,788	0	0	61	499	0
Apr.	3,434	30,243	0	0	59	483	0
May.	866	30,922	0	0	61	499	0
Jun.	10	30,644	0	0	59	483	0
Jul.	10	32,422	0	0	61	499	0
Aug.	10	33,189	0	0	61	499	0
Sep.	10	33,258	0	0	81	483	0
Oct.	1,313	22,245	0	0	84	499	0
Nov.	1,312	22,483	0	0	81	483	0
Dec.	10	15,018	0	0	84	499	0
Total	12,141	313,470	0	0	854	5,877	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-47. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-24.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	Loafing Lot
Jan.	10	27,314	0	0	325	869	0
Feb.	620	31,102	0	0	296	792	0
Mar.	3,062	63,485	0	0	243	869	0
Apr.	2,452	60,580	0	0	235	841	0
May.	620	55,922	0	0	243	869	0
Jun.	10	55,324	0	0	235	841	0
Jul.	10	58,417	0	0	243	869	0
Aug.	10	59,751	0	0	243	869	0
Sep.	10	61,927	0	0	315	841	0
Oct.	939	42,767	0	0	325	869	0
Nov.	938	43,187	0	0	315	841	0
Dec.	10	26,308	0	0	325	869	0
Total	8,690	586,086	0	0	3,345	10,234	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-48. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-26.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						Loafing Lot
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	
Jan.	5	30,250	0	0	418	1,563	0
Feb.	412	37,951	0	0	381	1,424	0
Mar.	2,039	87,854	0	0	351	1,563	0
Apr.	1,632	81,149	0	0	339	1,512	0
May.	412	65,523	0	0	351	1,563	0
Jun.	5	64,916	0	0	339	1,512	0
Jul.	5	68,352	0	0	351	1,563	0
Aug.	5	69,835	0	0	351	1,563	0
Sep.	5	75,682	0	0	404	1,512	0
Oct.	624	54,392	0	0	418	1,563	0
Nov.	624	54,856	0	0	404	1,512	0
Dec.	5	29,134	0	0	418	1,563	0
Total	5,776	719,893	0	0	4,524	18,412	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table E-49. North Fork of the Shenandoah River: Monthly nonpoint fecal coliform loadings in sub-watershed NFSL-27.

Month	Fecal Coliform loadings (x10 ¹⁰ cfu/month)						
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential ¹	Loafing Lot
Jan.	2	10,579	0	0	264	561	0
Feb.	143	15,001	0	0	240	511	0
Mar.	712	39,374	0	0	204	561	0
Apr.	570	35,303	0	0	197	543	0
May.	144	24,665	0	0	204	561	0
Jun.	2	24,410	0	0	197	543	0
Jul.	2	25,612	0	0	204	561	0
Aug.	2	26,132	0	0	204	561	0
Sep.	2	29,947	0	0	255	543	0
Oct.	218	22,478	0	0	264	561	0
Nov.	218	22,647	0	0	255	543	0
Dec.	2	10,187	0	0	264	561	0
Total	2,013	286,334	0	0	2,753	6,610	0

¹Includes Farmstead, Low Density Residential, and High Density Residential Loads

Appendix F: Fecal Coliform Loadings in Sub- Watersheds

Table F-1a. Annual nonpoint source loadings in sub-watershed MC-56.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	114,270	0.3%	114,270	0%
Pasture	19,164,533	47%	19,164,533	0%
Loafing Lots	0	0%	0	0%
Forest	32,333	0.1%	32,333	0%
Residential	21,354,707	53%	21,354,707	0%
Total	40,665,842	100%	40,665,842	0%

Table F-1b. Annual direct nonpoint source loadings in sub-watershed MC-56.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	15,963	62%	15,963	0%
Wildlife in Streams	9,727	38%	9,727	0%
Straight Pipes	0	0%	0	0%
Total	25,690	100%	25,690	0%

Table F-2a. Annual nonpoint source loadings in sub-watershed MC-57.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	132,340	0.1%	132,340	0%
Pasture	56,303,121	61%	56,303,121	0%
Loafing Lots	0	0%	0	0%
Forest	51,334	0.1%	51,334	0%
Residential	35,656,527	39%	35,656,527	0%
Total	92,143,322	100%	92,143,322	0%

Table F-2b. Annual direct nonpoint source loadings in sub-watershed MC-57.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	36,821	3%	36,821	0%
Wildlife in Streams	11,948	1%	11,948	0%
Straight Pipes	1,077,488	96%	1,077,488	0%
Total	1,126,256	100%	1,126,256	0%

Table F-3a. Annual nonpoint source loadings in sub-watershed MC-58.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	77,650	0.5%	77,650	0%
Pasture	11,088,945	70%	11,088,945	0%
Loafing Lots	0	0%	0	0%
Forest	21,408	0.1%	21,408	0%
Residential	4,638,310	29%	4,638,310	0%
Total	15,826,313	100%	15,826,313	0%

Table F-3b. Annual direct nonpoint source loadings in sub-watershed MC-58.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	21,310	78%	21,310	0%
Wildlife in Streams	6,094	22%	6,094	0%
Straight Pipes	0	0%	0	0%
Total	27,404	100%	27,404	0%

Table F-4a. Annual nonpoint source loadings in sub-watershed MC-59.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	355,084	0.4%	355,084	0%
Pasture	47,386,025	56%	47,386,025	0%
Loafing Lots	0	0%	0	0%
Forest	226,490	0.3%	226,490	0%
Residential	36,334,705	43%	36,334,705	0%
Total	84,302,303	100%	84,302,303	0%

Table F-4b. Annual direct nonpoint source loadings in sub-watershed MC-59.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	121,396	76%	121,396	0%
Wildlife in Streams	38,547	24%	38,547	0%
Straight Pipes	0	0%	0	0%
Total	159,943	100%	159,943	0%

Table F-5a. Annual nonpoint source loadings in sub-watershed MC-60.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	352,911	0.2%	352,911	0%
Pasture	83,955,824	59%	83,955,824	0%
Loafing Lots	0	0%	0	0%
Forest	144,102	0.1%	144,102	0%
Residential	56,759,028	40%	56,759,028	0%
Total	141,211,865	100%	141,211,865	0%

Table F-5b. Annual direct nonpoint source loadings in sub-watershed MC-60.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	67,788	1%	67,788	0%
Wildlife in Streams	27,742	0.5%	27,742	0%
Straight Pipes	5,960,880	98%	5,960,880	0%
Total	6,056,410	100%	6,056,410	0%

Table F-6a. Annual nonpoint source loadings in sub-watershed MC-61.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	170,459	0.4%	170,459	0%
Pasture	30,949,011	64%	30,949,011	0%
Loafing Lots	0	0%	0	0%
Forest	171,165	0.4%	171,165	0%
Residential	17,178,621	35%	17,178,621	0%
Total	48,469,255	100%	48,469,255	0%

Table F-6b. Annual direct nonpoint source loadings in sub-watershed MC-61.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	59,381	72%	59,381	0%
Wildlife in Streams	22,773	28%	22,773	0%
Straight Pipes	0	0%	0	0%
Total	82,154	100%	82,154	0%

Table F-7a. Annual nonpoint source loadings in sub-watershed MC-62.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	79,300	0.3%	79,300	0%
Pasture	8,938,652	37%	8,938,652	0%
Loafing Lots	0	0%	0	0%
Forest	403,331	2%	403,331	0%
Residential	14,926,672	61%	14,926,672	0%
Total	24,347,955	100%	24,347,955	0%

Table F-7b. Annual direct nonpoint source loadings in sub-watershed MC-62.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	30,861	40%	30,861	0%
Wildlife in Streams	45,600	60%	45,600	0%
Straight Pipes	0	0%	0	0%
Total	76,461	100%	76,461	0%

Table F-8a. Annual nonpoint source loadings in sub-watershed MC-63.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	12,251	0%	12,251	0%
Pasture	12,744,949	46%	12,744,949	0%
Loafing Lots	0	0%	0	0%
Forest	333,441	1%	333,441	0%
Residential	14,387,654	52%	14,387,654	0%
Total	27,478,295	100%	27,478,295	0%

Table F-8b. Annual direct nonpoint source loadings in sub-watershed MC-63.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	70,395	66%	70,395	0%
Wildlife in Streams	36,056	34%	36,056	0%
Straight Pipes	0	0%	0	0%
Total	106,452	100%	106,452	0%

Table F-9a. Annual nonpoint source loadings in sub-watershed MC-64.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	3,453	0%	3,453	0%
Pasture	1,662,100	17%	1,662,100	0%
Loafing Lots	0	0%	0	0%
Forest	296,461	3%	296,461	0%
Residential	7,565,332	79%	0	100%
Total	9,527,346	100%	1,962,014	79%

Table F-9b. Annual direct nonpoint source loadings in sub-watershed MC-64.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	20,778	35%	20,778	0%
Wildlife in Streams	37,790	65%	37,790	0%
Straight Pipes	0	0%	0	0%
Total	58,568	100%	58,568	0%

Table G-10a. Required annual reductions in nonpoint sources in sub-watershed SC-29.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	725,479	0.1%	725,479	0%
Pasture	14,699,350	2%	14,699,350	0%
Loafing Lots	0	0%	0	0%
Forest	306,619	0.1%	306,619	0%
Residential	591,793,208	97%	591,793,208	0%
Total	607,524,656	100%	607,524,656	0%

Table G-10b. Required annual reductions in direct nonpoint sources in sub-watershed SC-29.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	18,167	0%	18,167	0%
Wildlife in Streams	87,364	0.2%	87,364	0%
Straight Pipes	50,316,840	100%	50,316,840	0%
Total	50,422,372	100%	50,422,372	0%

Table G-11a. Required annual reductions in nonpoint sources in sub-watershed SC-30.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	3,896	0%	3,896	0%
Pasture	2,544,226	14%	2,544,226	0%
Loafing Lots	0	0%	0	0%
Forest	40,489	0.2%	40,489	0%
Residential	15,052,683	85%	15,052,683	0%
Total	17,641,294	100%	17,641,294	0%

Table F-11b. Annual direct nonpoint source loadings in sub-watershed SC-30.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	684	0.1%	684	0%
Wildlife in Streams	11,281	1%	11,281	0%
Straight Pipes	935,040	99%	935,040	0%
Total	947,005	100%	947,005	0%

Table F-12a. Annual nonpoint source loadings in sub-watershed SC-31.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	24,229	0.2%	24,229	0%
Pasture	1,794,163	12%	1,794,163	0%
Loafing Lots	0	0%	0	0%
Forest	77,437	0.5%	77,437	0%
Residential	13,123,250	87%	13,123,250	0%
Total	15,019,079	100%	15,019,079	0%

Table F-12b. Annual direct nonpoint source loadings in sub-watershed SC-31.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	3,306	0.4%	3,306	0%
Wildlife in Streams	23,963	3%	23,963	0%
Straight Pipes	869,295	97%	869,295	0%
Total	896,564	100%	896,564	0%

Table F-13a. Annual nonpoint source loadings in sub-watershed SC-32.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	180,050	0.1%	180,050	0%
Pasture	18,447,307	7%	18,447,307	0%
Loafing Lots	0	0%	0	0%
Forest	424,190	0.2%	424,190	0%
Residential	261,523,566	93%	261,523,566	0%
Total	280,575,113	100%	280,575,113	0%

Table F-13b. Annual direct nonpoint source loadings in sub-watershed SC-32.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	36,937	0.1%	36,937	0%
Wildlife in Streams	122,321	0.3%	122,321	0%
Straight Pipes	36,159,750	100%	36,159,750	0%
Total	36,319,008	100%	36,319,008	0%

Table F-14a. Annual nonpoint source loadings in sub-watershed SC-34.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	333,566	0.2%	333,566	0%
Pasture	27,859,286	13%	27,859,286	0%
Loafing Lots	0	0%	0	0%
Forest	480,304	0.2%	480,304	0%
Residential	193,127,033	87%	193,127,033	0%
Total	221,800,189	100%	221,800,189	0%

Table F-14b. Annual direct nonpoint source loadings in sub-watershed SC-34.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	28,576	0.1%	28,576	0%
Wildlife in Streams	121,699	0.4%	121,699	0%
Straight Pipes	29,103,120	99%	29,103,120	0%
Total	29,253,395	100%	29,253,395	0%

Table F-15a. Annual nonpoint source loadings in sub-watershed SC-37.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	117,344	0.1%	117,344	0%
Pasture	14,578,042	16%	14,578,042	0%
Loafing Lots	0	0%	0	0%
Forest	596,350	0.7%	596,350	0%
Residential	73,377,264	83%	73,377,264	0%
Total	88,669,000	100%	88,669,000	0%

Table F-15b. Annual direct nonpoint source loadings in sub-watershed SC-37.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	39,216	0.2%	39,216	0%
Wildlife in Streams	152,789	0.9%	152,789	0%
Straight Pipes	16,005,255	99%	16,005,255	0%
Total	16,197,261	100%	16,197,261	0%

Table F-16a. Annual nonpoint source loadings in sub-watershed SC-38.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	345,344	0.9%	345,344	0%
Pasture	8,949,358	22%	8,949,358	0%
Loafing Lots	0	0%	0	0%
Forest	125,730	0.3%	125,730	0%
Residential	30,517,003	76%	30,517,003	0%
Total	39,937,435	100%	39,937,435	0%

Table F-16b. Annual direct nonpoint source loadings in sub-watershed SC-38.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	5,363	0.2%	5,363	0%
Wildlife in Streams	32,291	1%	32,291	0%
Straight Pipes	3,038,880	99%	3,038,880	0%
Total	3,076,534	100%	3,076,534	0%

Table F-17a. Annual nonpoint source loadings in sub-watershed SC-39.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	83,799	0.2%	83,799	0%
Pasture	6,068,010	12%	6,068,010	0%
Loafing Lots	0	0%	0	0%
Forest	97,388	0.2%	97,388	0%
Residential	44,862,744	88%	44,862,744	0%
Total	51,111,941	100%	51,111,941	0%

Table F-17b. Annual direct nonpoint source loadings in sub-watershed SC-39.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	2,414	0%	2,414	0%
Wildlife in Streams	19,031	0.2%	19,031	0%
Straight Pipes	9,313,875	100%	9,313,875	0%
Total	9,335,320	100%	9,335,320	0%

Table F-18a. Annual nonpoint source loadings in sub-watershed SC-40.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	66,122	0.1%	66,122	0%
Pasture	17,679,903	27%	17,679,903	0%
Loafing Lots	0	0%	0	0%
Forest	489,488	0.7%	489,488	0%
Residential	47,095,700	72%	47,095,700	0%
Total	65,331,213	100%	65,331,213	0%

Table F-18b. Annual direct nonpoint source loadings in sub-watershed SC-40.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	7,142	0.1%	7,142	0%
Wildlife in Streams	64,258	0.7%	64,258	0%
Straight Pipes	9,386,925	99%	9,386,925	0%
Total	9,458,324	100%	9,458,324	0%

Table F-20a. Annual nonpoint source loadings in sub-watershed SC-41.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	4,666	0%	4,666	0%
Pasture	691,134	2%	691,134	0%
Loafing Lots	0	0%	0	0%
Forest	795,481	2%	795,481	0%
Residential	34,483,070	96%	34,483,070	0%
Total	35,974,350	100%	35,974,350	0%

Table F-20b. Annual direct nonpoint source loadings in sub-watershed SC-41.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	867	0%	867	0%
Wildlife in Streams	123,162	1%	123,162	0%
Straight Pipes	10,300,050	99%	10,300,050	0%
Total	10,424,080	100%	10,424,080	0%

Table F-21a. Annual nonpoint source loadings in sub-watershed SC-42.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	1,882	0%	1,882	0%
Pasture	906,038	11%	906,038	0%
Loafing Lots	0	0%	0	0%
Forest	382,934	4%	382,934	0%
Residential	7,235,237	85%	7,235,237	0%
Total	8,526,091	100%	8,526,091	0%

Table F-21b. Annual direct nonpoint source loadings in sub-watershed SC-42.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	4,337	0.2%	4,337	0%
Wildlife in Streams	65,608	3%	65,608	0%
Straight Pipes	2,388,735	97%	2,388,735	0%
Total	2,458,680	100%	2,458,680	0%

Table F-22a. Annual nonpoint source loadings in sub-watershed SC-43.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	82,850	0.2%	82,850	0%
Pasture	7,290,566	14%	7,290,566	0%
Loafing Lots	0	0%	0	0%
Forest	672,971	1%	672,971	0%
Residential	42,950,661	84%	42,950,661	0%
Total	50,997,048	100%	50,997,048	0%

Table F-22b. Annual direct nonpoint source loadings in sub-watershed SC-43.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	5,768	0%	5,768	0%
Wildlife in Streams	134,061	1%	134,061	0%
Straight Pipes	12,476,940	99%	12,476,940	0%
Total	12,616,769	100%	12,616,769	0%

Table F-23a. Annual nonpoint source loadings in sub-watershed SC-46.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	8,783	0%	8,783	0%
Pasture	396,521	1%	396,521	0%
Loafing Lots	0	0%	0	0%
Forest	555,979	2%	555,979	0%
Residential	25,910,105	96%	25,910,105	0%
Total	26,871,388	100%	26,871,388	0%

Table F-23b. Annual direct nonpoint source loadings in sub-watershed SC-46.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	1,214	0%	1,214	0%
Wildlife in Streams	93,667	1%	93,667	0%
Straight Pipes	8,590,680	99%	8,590,680	0%
Total	8,685,561	100%	8,685,561	0%

Table F-24a. Annual nonpoint source loadings in sub-watershed SC-47.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	2,218	0.1%	2,218	0%
Pasture	1,544,034	40%	1,544,034	0%
Loafing Lots	0	0%	0	0%
Forest	191,615	5%	191,615	0%
Residential	2,121,372	55%	0	100%
Total	3,859,239	100%	1,737,867	55%

Table F-24b. Annual direct nonpoint source loadings in sub-watershed SC-47.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	8,289	0.9%	8,289	0%
Wildlife in Streams	43,337	5%	43,337	0%
Straight Pipes	832,770	94%	832,770	0%
Total	884,396	100%	884,396	0%

Table F-25a. Annual nonpoint source loadings in sub-watershed SC-48.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	37,959	0.2%	37,959	0%
Pasture	1,812,092	11%	1,812,092	0%
Loafing Lots	0	0%	0	0%
Forest	356,170	2%	356,170	0%
Residential	14,638,124	87%	14,638,124	0%
Total	16,844,346	100%	16,844,346	0%

Table F-25b. Annual direct nonpoint source loadings in sub-watershed SC-48.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	7,228	0.3%	7,228	0%
Wildlife in Streams	54,930	2%	54,930	0%
Straight Pipes	2,235,330	97%	2,235,330	0%
Total	2,297,488	100%	2,297,488	0%

Table F-26a. Annual nonpoint source loadings in sub-watershed SC-50.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	29,094	0.1%	29,094	0%
Pasture	3,676,790	14%	3,676,790	0%
Loafing Lots	0	0%	0	0%
Forest	440,960	2%	440,960	0%
Residential	22,106,574	84%	22,106,574	0%
Total	26,253,418	100%	26,253,418	0%

Table F-26b. Annual direct nonpoint source loadings in sub-watershed SC-50.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	9,339	0.3%	9,339	0%
Wildlife in Streams	72,886	3%	72,886	0%
Straight Pipes	2,746,680	97%	2,746,680	0%
Total	2,828,905	100%	2,828,905	0%

Table F-27a. Annual nonpoint source loadings in sub-watershed SC-51.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	2,467	0%	2,467	0%
Pasture	1,021,817	17%	1,021,817	0%
Loafing Lots	0	0%	0	0%
Forest	1,046,106	17%	1,046,106	0%
Residential	3,940,500	66%	3,940,500	0%
Total	6,010,890	100%	6,010,890	0%

Table F-27b. Annual direct nonpoint source loadings in sub-watershed SC-51.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	5,638	0.9%	5,638	0%
Wildlife in Streams	57,322	9%	57,322	0%
Straight Pipes	555,180	90%	555,180	0%
Total	618,140	100%	618,140	0%

Table F-28a. Annual nonpoint source loadings in sub-watershed SC-52.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	14,542	0.2%	14,542	0%
Pasture	1,310,970	19%	1,310,970	0%
Loafing Lots	0	0%	0	0%
Forest	242,146	3%	242,146	0%
Residential	5,382,141	77%	5,382,141	0%
Total	6,949,799	100%	6,949,799	0%

Table F-28b. Annual direct nonpoint source loadings in sub-watershed SC-52.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	1,773	0.3%	1,773	0%
Wildlife in Streams	41,243	6%	41,243	0%
Straight Pipes	664,755	94%	664,755	0%
Total	707,771	100%	707,771	0%

Table F-29a. Annual nonpoint source loadings in sub-watershed SC-54.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	45,550	0.3%	45,550	0%
Pasture	865,265	6%	865,265	0%
Loafing Lots	0	0%	0	0%
Forest	375,240	3%	375,240	0%
Residential	12,194,054	90%	12,194,054	0%
Total	13,480,109	100%	13,480,109	0%

Table F-29b. Annual direct nonpoint source loadings in sub-watershed SC-54.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	2,819	0.1%	2,819	0%
Wildlife in Streams	63,626	3%	63,626	0%
Straight Pipes	2,016,180	97%	2,016,180	0%
Total	2,082,625	100%	2,082,625	0%

Table F-30a. Annual nonpoint source loadings in sub-watershed SC-55.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	68,572	0.1%	68,572	0%
Pasture	3,410,980	4%	3,410,980	0%
Loafing Lots	0	0%	0	0%
Forest	887,050	0.9%	887,050	0%
Residential	90,665,642	95%	90,665,642	0%
Total	95,032,244	100%	95,032,244	0%

Table F-30b. Annual direct nonpoint source loadings in sub-watershed SC-55.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	12,216	0.1%	12,216	0%
Wildlife in Streams	130,145	0.9%	130,145	0%
Straight Pipes	13,696,875	99%	13,696,875	0%
Total	13,839,236	100%	13,839,236	0%

Table F-31a. Annual nonpoint source loadings in sub-watershed NFSL-1.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	721,315	1%	721,315	0%
Pasture	63,019,737	89%	63,019,737	0%
Loafing Lots	0	0%	0	0%
Forest	705,855	1.0%	705,855	0%
Residential	6,359,837	9%	6,359,837	0%
Total	70,806,743	100%	70,806,743	0%

Table F-31b. Annual direct nonpoint source loadings in sub-watershed NFSL-1.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	183,673	52%	183,673	0%
Wildlife in Streams	167,963	48%	167,963	0%
Straight Pipes	0	0%	0	0%
Total	351,636	100%	351,636	0%

Table F-32a. Annual nonpoint source loadings in sub-watershed NFSL-3.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	707,904	0.4%	707,904	0%
Pasture	164,310,832	96%	164,310,832	0%
Loafing Lots	0	0%	0	0%
Forest	2,213,118	1%	2,213,118	0%
Residential	3,899,234	2%	3,899,234	0%
Total	171,131,088	100%	171,131,088	0%

Table F-32b. Annual direct nonpoint source loadings in sub-watershed NFSL-3.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	554,763	51%	554,763	0%
Wildlife in Streams	526,940	49%	526,940	0%
Straight Pipes	0	0%	0	0%
Total	1,081,703	100%	1,081,703	0%

Table F-33a. Annual nonpoint source loadings in sub-watershed NFSL-4.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	1,444,387	1%	1,444,387	0%
Pasture	118,957,779	95%	118,957,779	0%
Loafing Lots	0	0%	0	0%
Forest	951,300	0.8%	951,300	0%
Residential	3,397,227	3%	3,397,227	0%
Total	124,750,692	100%	124,750,692	0%

Table F-33b. Annual direct nonpoint source loadings in sub-watershed NFSL-4.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	268,221	56%	268,221	0%
Wildlife in Streams	212,470	44%	212,470	0%
Straight Pipes	0	0%	0	0%
Total	480,691	100%	480,691	0%

Table F-34a. Annual nonpoint source loadings in sub-watershed NFSL-5.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	328,724	0.6%	328,724	0%
Pasture	53,818,062	95%	53,818,062	0%
Loafing Lots	0	0%	0	0%
Forest	860,870	2%	860,870	0%
Residential	1,524,188	3%	1,524,188	0%
Total	56,531,844	100%	56,531,844	0%

Table F-34b. Annual direct nonpoint source loadings in sub-watershed NFSL-5.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	179,168	45%	179,168	0%
Wildlife in Streams	216,779	55%	216,779	0%
Straight Pipes	0	0%	0	0%
Total	395,947	100%	395,947	0%

Table F-35a. Annual nonpoint source loadings in sub-watershed NFSL-7.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	1,326,683	1%	1,326,683	0%
Pasture	120,467,167	95%	120,467,167	0%
Loafing Lots	0	0%	0	0%
Forest	876,813	0.7%	876,813	0%
Residential	4,271,095	3%	4,271,095	0%
Total	126,941,759	100%	126,941,759	0%

Table F-35b. Annual direct nonpoint source loadings in sub-watershed NFSL-7.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	197,190	52%	197,190	0%
Wildlife in Streams	180,454	48%	180,454	0%
Straight Pipes	0	0%	0	0%
Total	377,645	100%	377,645	0%

Table F-36a. Annual nonpoint source loadings in sub-watershed NFSL-8.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	900,250	1.0%	900,250	0%
Pasture	87,561,222	93%	87,561,222	0%
Loafing Lots	0	0%	0	0%
Forest	457,843	0.5%	457,843	0%
Residential	5,735,508	6%	5,735,508	0%
Total	94,654,823	100%	94,654,823	0%

Table F-36b. Annual direct nonpoint source loadings in sub-watershed NFSL-8.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	116,419	50%	116,419	0%
Wildlife in Streams	116,239	50%	116,239	0%
Straight Pipes	0	0%	0	0%
Total	232,659	100%	232,659	0%

Table F-37a. Annual nonpoint source loadings in sub-watershed NFSL-9.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	392,120	0.7%	392,120	0%
Pasture	48,924,848	92%	48,924,848	0%
Loafing Lots	0	0%	0	0%
Forest	905,547	2%	905,547	0%
Residential	2,790,000	5%	2,790,000	0%
Total	53,012,516	100%	53,012,516	0%

Table F-37b. Annual direct nonpoint source loadings in sub-watershed NFSL-9.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	167,837	43%	167,837	0%
Wildlife in Streams	224,828	57%	224,828	0%
Straight Pipes	0	0%	0	0%
Total	392,665	100%	392,665	0%

Table F-38a. Annual nonpoint source loadings in sub-watershed NFSL-10.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	3,162,039	2%	3,162,039	0%
Pasture	155,710,474	95%	155,710,474	0%
Loafing Lots	0	0%	0	0%
Forest	1,154,542	0.7%	1,154,542	0%
Residential	3,980,714	2%	3,980,714	0%
Total	164,007,769	100%	164,007,769	0%

Table F-38b. Annual direct nonpoint source loadings in sub-watershed NFSL-10.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	294,858	52%	294,858	0%
Wildlife in Streams	251,913	45%	251,913	0%
Straight Pipes	18,555	3%	18,555	0%
Total	565,325	100%	565,325	0%

Table F-39a. Annual nonpoint source loadings in sub-watershed NFSL-12.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	1,996,955	1%	1,996,955	0%
Pasture	184,998,633	95%	184,998,633	0%
Loafing Lots	0	0%	0	0%
Forest	1,734,733	0.9%	1,734,733	0%
Residential	6,631,033	3%	6,631,033	0%
Total	195,361,354	100%	195,361,354	0%

Table F-39b. Annual direct nonpoint source loadings in sub-watershed NFSL-12.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	264,842	45%	264,842	0%
Wildlife in Streams	328,629	55%	328,629	0%
Straight Pipes	0	0%	0	0%
Total	593,471	100%	593,471	0%

Table F-40a. Annual nonpoint source loadings in sub-watershed NFSL-14.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	471,102	6%	471,102	0%
Pasture	6,839,810	89%	6,839,810	0%
Loafing Lots	0	0%	0	0%
Forest	76,982	1%	76,982	0%
Residential	308,052	4%	308,052	0%
Total	7,695,946	100%	7,695,946	0%

Table F-40b. Annual direct nonpoint source loadings in sub-watershed NFSL-14.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	22,794	49%	22,794	0%
Wildlife in Streams	23,854	51%	23,854	0%
Straight Pipes	0	0%	0	0%
Total	46,648	100%	46,648	0%

Table F-41a. Annual nonpoint source loadings in sub-watershed NFSL-16.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	3,069,148	2%	3,069,148	0%
Pasture	165,841,772	97%	165,841,772	0%
Loafing Lots	0	0%	0	0%
Forest	604,569	0.4%	604,569	0%
Residential	2,149,094	1%	2,149,094	0%
Total	171,664,583	100%	171,664,583	0%

Table F-41b. Annual direct nonpoint source loadings in sub-watershed NFSL-16.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	198,052	55%	198,052	0%
Wildlife in Streams	164,375	45%	164,375	0%
Straight Pipes	0	0%	0	0%
Total	362,427	100%	362,427	0%

Table F-42a. Annual nonpoint source loadings in sub-watershed NFSL-17.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	2,368,286	2%	2,368,286	0%
Pasture	135,283,712	95%	135,283,712	0%
Loafing Lots	0	0%	0	0%
Forest	304,546	0.2%	304,546	0%
Residential	3,758,906	3%	3,758,906	0%
Total	141,715,450	100%	141,715,450	0%

Table F-42b. Annual direct nonpoint source loadings in sub-watershed NFSL-17.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	77,425	53%	77,425	0%
Wildlife in Streams	68,114	47%	68,114	0%
Straight Pipes	0	0%	0	0%
Total	145,539	100%	145,539	0%

Table F-43a. Annual nonpoint source loadings in sub-watershed NFSL-18.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	2,948,861	1%	2,948,861	0%
Pasture	235,396,253	96%	235,396,253	0%
Loafing Lots	0	0%	0	0%
Forest	582,357	0.2%	582,357	0%
Residential	5,091,468	2%	5,091,468	0%
Total	244,018,940	100%	244,018,940	0%

Table F-43b. Annual direct nonpoint source loadings in sub-watershed NFSL-18.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	348,529	69%	348,529	0%
Wildlife in Streams	157,091	31%	157,091	0%
Straight Pipes	0	0%	0	0%
Total	505,619	100%	505,619	0%

Table F-44a. Annual nonpoint source loadings in sub-watershed NFSL-19.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	1,324,765	1%	1,324,765	0%
Pasture	102,172,582	97%	102,172,582	0%
Loafing Lots	0	0%	0	0%
Forest	248,981	0.2%	248,981	0%
Residential	2,113,183	2%	2,113,183	0%
Total	105,859,511	100%	105,859,511	0%

Table F-44b. Annual direct nonpoint source loadings in sub-watershed NFSL-19.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	39,822	43%	39,822	0%
Wildlife in Streams	52,101	57%	52,101	0%
Straight Pipes	0	0%	0	0%
Total	91,924	100%	91,924	0%

Table F-45a. Annual nonpoint source loadings in sub-watershed NFSL-20.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	272,438	0.4%	272,438	0%
Pasture	69,731,109	98%	69,731,109	0%
Loafing Lots	0	0%	0	0%
Forest	268,819	0.4%	268,819	0%
Residential	1,029,959	1%	1,029,959	0%
Total	71,302,324	100%	71,302,324	0%

Table F-45b. Annual direct nonpoint source loadings in sub-watershed NFSL-20.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	139,544	65%	139,544	0%
Wildlife in Streams	73,811	35%	73,811	0%
Straight Pipes	0	0%	0	0%
Total	213,355	100%	213,355	0%

Table F-46a. Annual nonpoint source loadings in sub-watershed NFSL-21.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	95,366	0.4%	95,366	0%
Pasture	20,871,841	97%	20,871,841	0%
Loafing Lots	0	0%	0	0%
Forest	108,234	0.5%	108,234	0%
Residential	379,349	2%	379,349	0%
Total	21,454,789	100%	21,454,789	0%

Table F-46b. Annual direct nonpoint source loadings in sub-watershed NFSL-21.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	24,516	44%	24,516	0%
Wildlife in Streams	31,602	56%	31,602	0%
Straight Pipes	0	0%	0	0%
Total	56,118	100%	56,118	0%

Table F-47a. Annual nonpoint source loadings in sub-watershed NFSL-22.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	1,214,050	4%	1,214,050	0%
Pasture	31,347,005	94%	31,347,005	0%
Loafing Lots	0	0%	0	0%
Forest	85,428	0.3%	85,428	0%
Residential	587,719	2%	587,719	0%
Total	33,234,202	100%	33,234,202	0%

Table F-47b. Annual direct nonpoint source loadings in sub-watershed NFSL-22.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	31,142	56%	31,142	0%
Wildlife in Streams	24,932	44%	24,932	0%
Straight Pipes	0	0%	0	0%
Total	56,075	100%	56,075	0%

Table F-48a. Annual nonpoint source loadings in sub-watershed NFSL-24.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	869,007	1%	869,007	0%
Pasture	58,608,553	96%	58,608,553	0%
Loafing Lots	0	0%	0	0%
Forest	334,473	0.5%	334,473	0%
Residential	1,023,431	2%	1,023,431	0%
Total	60,835,464	100%	60,835,464	0%

Table F-48b. Annual direct nonpoint source loadings in sub-watershed NFSL-24.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	152,133	63%	152,133	0%
Wildlife in Streams	88,521	37%	88,521	0%
Straight Pipes	0	0%	0	0%
Total	240,655	100%	240,655	0%

Table F-49a. Annual nonpoint source loadings in sub-watershed NFSL-26.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	577,587	0.8%	577,587	0%
Pasture	71,989,346	96%	71,989,346	0%
Loafing Lots	0	0%	0	0%
Forest	452,430	0.6%	452,430	0%
Residential	1,841,189	2%	1,841,189	0%
Total	74,860,552	100%	74,860,552	0%

Table F-49b. Annual direct nonpoint source loadings in sub-watershed NFSL-26.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	120,594	56%	120,594	0%
Wildlife in Streams	76,401	35%	76,401	0%
Straight Pipes	19,431	9%	19,431	0%
Total	216,426	100%	216,426	0%

Table F-50a. Annual nonpoint source loadings in sub-watershed NFSL-27.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	201,343	0.7%	201,343	0%
Pasture	28,633,444	96%	28,633,444	0%
Loafing Lots	0	0%	0	0%
Forest	275,252	0.9%	275,252	0%
Residential	660,987	2%	660,987	0%
Total	29,771,027	100%	29,771,027	0%

Table F-50b. Annual direct nonpoint source loadings in sub-watershed NFSL-27.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	80,572	57%	80,572	0%
Wildlife in Streams	61,480	43%	61,480	0%
Straight Pipes	0	0%	0	0%
Total	142,052	100%	142,052	0%

Appendix G: Required Reductions in Fecal Coliform Loads by Sub-Watershed Allocation Scenerio

Table G-1a. Required annual reductions in nonpoint sources in sub-watershed MC-56.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	114,270	0.3%	11,427	90%
Pasture	19,164,533	47%	1,916,453	90%
Loafing Lots	0	0%	0	
Forest	32,333	0.1%	32,333	0%
Residential	21,354,707	53%	2,135,471	90%
Total	40,665,842	100%	4,095,684	90%

Table G-1b. Required annual reductions in direct nonpoint sources in sub-watershed MC-56.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	15,963	62%	2,394	85%
Wildlife in Streams	9,727	38%	4,864	50%
Straight Pipes	0	0%	0	100%
Total	25,690	100%	7,258	72%

Table G-2a. Required annual reductions in nonpoint sources in sub-watershed MC-57.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	132,340	0.1%	13,234	90%
Pasture	56,303,121	61%	5,630,312	90%
Loafing Lots	0	0%	0	
Forest	51,334	0.1%	51,334	0%
Residential	35,656,527	39%	3,565,653	90%
Total	92,143,322	100%	9,260,533	90%

Table G-2b. Required annual reductions in direct nonpoint sources in sub-watershed MC-57.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	36,821	3%	5,523	85%
Wildlife in Streams	11,948	1%	5,974	50%
Straight Pipes	1,077,488	96%	0	100%
Total	1,126,256	100%	11,497	99%

Table G-3a. Required annual reductions in nonpoint sources in sub-watershed MC-58.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	77,650	0.5%	7,765	90%
Pasture	11,088,945	70%	1,108,895	90%
Loafing Lots	0	0%	0	
Forest	21,408	0.1%	21,408	0%
Residential	4,638,310	29%	463,831	90%
Total	15,826,313	100%	1,601,899	90%

Table G-3b. Required annual reductions in direct nonpoint sources in sub-watershed MC-58.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	21,310	78%	3,197	85%
Wildlife in Streams	6,094	22%	3,047	50%
Straight Pipes	0	0%	0	100%
Total	27,404	100%	6,244	77%

Table G-4a. Required annual reductions in nonpoint sources in sub-watershed MC-59.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	355,084	0.4%	35,508	90%
Pasture	47,386,025	56%	4,738,603	90%
Loafing Lots	0	0%	0	
Forest	226,490	0.3%	226,490	0%
Residential	36,334,705	43%	3,633,471	90%
Total	84,302,303	100%	8,634,071	90%

Table G-4b. Required annual reductions in direct nonpoint sources in sub-watershed MC-59.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	121,396	76%	18,209	85%
Wildlife in Streams	38,547	24%	19,274	50%
Straight Pipes	0	0%	0	100%
Total	159,943	100%	37,483	77%

Table G-5a. Required annual reductions in nonpoint sources in sub-watershed MC-60.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	352,911	0.2%	35,291	90%
Pasture	83,955,824	59%	8,395,582	90%
Loafing Lots	0	0%	0	
Forest	144,102	0.1%	144,102	0%
Residential	56,759,028	40%	5,675,903	90%
Total	141,211,865	100%	35,291	90%

Table G-5b. Required annual reductions in direct nonpoint sources in sub-watershed MC-60.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	67,788	1%	10,168	85%
Wildlife in Streams	27,742	0.5%	13,871	50%
Straight Pipes	5,960,880	98%	0	100%
Total	6,056,410	100%	24,039	100%

Table G-6a. Required annual reductions in nonpoint sources in sub-watershed MC-61.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	170,459	0.4%	17,046	90%
Pasture	30,949,011	64%	3,094,901	90%
Loafing Lots	0	0%	0	
Forest	171,165	0.4%	171,165	0%
Residential	17,178,621	35%	1,717,862	90%
Total	48,469,255	100%	5,000,974	90%

Table G-6b. Required annual reductions in direct nonpoint sources in sub-watershed MC-61.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	59,381	72%	8,907	85%
Wildlife in Streams	22,773	28%	11,387	50%
Straight Pipes	0	0%	0	100%
Total	82,154	100%	20,294	75%

Table G-7a. Required annual reductions in nonpoint sources in sub-watershed MC-62.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	79,300	0.3%	7,930	90%
Pasture	8,938,652	37%	893,865	90%
Loafing Lots	0	0%	0	
Forest	403,331	2%	403,331	0%
Residential	14,926,672	61%	1,492,667	90%
Total	24,347,955	100%	2,797,793	89%

Table G-7b. Required annual reductions in direct nonpoint sources in sub-watershed MC-62.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	30,861	40%	4,629	85%
Wildlife in Streams	45,600	60%	22,800	50%
Straight Pipes	0	0%	0	100%
Total	76,461	100%	27,429	64%

Table G-8a. Required annual reductions in nonpoint sources in sub-watershed MC-63.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	12,251	0%	1,225	90%
Pasture	12,744,949	46%	1,274,495	90%
Loafing Lots	0	0%	0	
Forest	333,441	1%	333,441	0%
Residential	14,387,654	52%	1,438,765	90%
Total	27,478,295	100%	3,047,926	89%

Table G-8b. Required annual reductions in direct nonpoint sources in sub-watershed MC-63.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	70,395	66%	10,559	85%
Wildlife in Streams	36,056	34%	18,028	50%
Straight Pipes	0	0%	0	100%
Total	106,452	100%	28,587	73%

Table G-9a. Required annual reductions in nonpoint sources in sub-watershed MC-64.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	3,453	0%	345	90%
Pasture	1,662,100	17%	166,210	90%
Loafing Lots	0	0%	0	
Forest	296,461	3%	296,461	0%
Residential	7,565,332	79%	756,533	90%
Total	9,527,346	100%	1,219,550	87%

Table G-9b. Required annual reductions in direct nonpoint sources in sub-watershed MC-64.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	20,778	35%	3,117	85%
Wildlife in Streams	37,790	65%	18,895	50%
Straight Pipes	0	0%	0	100%
Total	58,568	100%	22,012	62%

Table G-10a. Required annual reductions in nonpoint sources in sub-watershed SC-29.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	725,479	0.1%	72,548	90%
Pasture	54,642,028	8%	5,464,203	90%
Loafing Lots	0	0%	0	
Forest	306,619	0%	306,619	0%
Residential	591,793,208	91%	59,179,321	90%
Total	647,467,333	100%	65,022,691	90%

Table G-10b. Required annual reductions in direct nonpoint sources in sub-watershed SC-29.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	124,900	0.2%	6,245	95%
Wildlife in Streams	87,364	0.2%	26,209	70%
Straight Pipes	5,031	100%	0	100%
Total	217,295	100%	32,454	85%

Table G-11a. Required annual reductions in nonpoint sources in sub-watershed SC-30.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	18,491	0.1%	1,849	90%
Pasture	11,600,739	43%	1,160,074	90%
Loafing Lots	0	0%	0	
Forest	40,489	0.2%	40,489	0%
Residential	15,052,683	56%	1,505,268	90%
Total	26,712,401	100%	2,707,680	90%

Table G-11b. Required annual reductions in direct nonpoint sources in sub-watershed SC-30.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	4,704	0.5%	235	95%
Wildlife in Streams	11,281	1%	3,384	70%
Straight Pipes	935,040	98%	0	100%
Total	951,025	100%	3,620	100%

Table G-12a. Required annual reductions in nonpoint sources in sub-watershed SC-31.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	49,687	0.2%	4,969	90%
Pasture	8,002,320	38%	800,232	90%
Loafing Lots	0	0%	0	
Forest	77,437	0.4%	77,437	0%
Residential	13,123,250	62%	1,312,325	90%
Total	21,252,694	100%	2,194,963	90%

Table G-12b. Required annual reductions in direct nonpoint sources in sub-watershed SC-31.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	22,727	2%	1,136	95%
Wildlife in Streams	23,963	3%	7,189	70%
Straight Pipes	869,295	95%	0	100%
Total	915,986	100%	8,325	99%

Table G-13a. Required annual reductions in nonpoint sources in sub-watershed SC-32.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	180,050	0.1%	18,005	90%
Pasture	83,577,939	24%	8,357,794	90%
Loafing Lots	0	0%	0	
Forest	424,190	0.1%	424,190	0%
Residential	261,523,566	76%	26,152,357	90%
Total	345,705,745	100%	34,952,346	90%

Table G-13b. Required annual reductions in direct nonpoint sources in sub-watershed SC-32.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	253,942	0.7%	12,697	95%
Wildlife in Streams	122,321	0.3%	36,696	70%
Straight Pipes	36,159,750	99%	0	100%
Total	36,536,013	100%	49,393	99%

Table G-14a. Required annual reductions in nonpoint sources in sub-watershed SC-34.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	670,107	0.2%	3,351	90%
Pasture	109,409,989	36%	547,049	90%
Loafing Lots	0	0%	0	
Forest	480,304	0.2%	480,304	0%
Residential	193,127,033	64%	965,634	90%
Total	303,687,433	100%	1,996,338	90%

Table G-14b. Required annual reductions in direct nonpoint sources in sub-watershed SC-34.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	196,461	0.7%	12,697	95%
Wildlife in Streams	121,699	0.4%	36,696	70%
Straight Pipes	29,103,120	99%	0	100%
Total	29,421,280	100%	49,393	99%

Table G-15a. Required annual reductions in nonpoint sources in sub-watershed SC-37.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	117,344	0.1%	587	90%
Pasture	54,347,874	42%	271,739	90%
Loafing Lots	0	0%	0	
Forest	596,350	0.5%	596,350	0%
Residential	73,377,264	57%	366,886	90%
Total	128,438,832	100%	1,235,562	90%

Table G-15b. Required annual reductions in direct nonpoint sources in sub-watershed SC-37.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	269,613	2%	13,481	95%
Wildlife in Streams	152,789	0.9%	152,789	70%
Straight Pipes	16,005,255	97%	0	100%
Total	16,427,657	100%	166,270	99%

Table G-16a. Required annual reductions in nonpoint sources in sub-watershed SC-38.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	345,344	0.6%	1,727	90%
Pasture	29,109,856	48%	145,549	90%
Loafing Lots	0	0%	0	
Forest	125,730	0.2%	125,730	0%
Residential	30,517,003	51%	152,585	90%
Total	60,097,933	100%	425,591	90%

Table G-16b. Required annual reductions in direct nonpoint sources in sub-watershed SC-38.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	36,874	1%	1,844	95%
Wildlife in Streams	32,291	1%	32,291	70%
Straight Pipes	3,038,880	98%	0	100%
Total	3,108,045	100%	34,135	99%

Table G-17a. Required annual reductions in nonpoint sources in sub-watershed SC-39.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	170,564	0.2%	853	90%
Pasture	27,278,525	38%	136,392	90%
Loafing Lots	0	0%	0	
Forest	97,388	0.1%	97,388	0%
Residential	44,862,744	62%	224,314	90%
Total	72,409,222	100%	458,947	90%

Table G-17b. Required annual reductions in direct nonpoint sources in sub-watershed SC-39.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	16,598	0.2%	830	95%
Wildlife in Streams	19,031	0.2%	19,031	70%
Straight Pipes	9,313,875	100%	0	100%
Total	9,349,504	100%	19,861	99%

Table G-18a. Required annual reductions in nonpoint sources in sub-watershed SC-40.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	123,555	0.1%	618	90%
Pasture	54,102,829	53%	270,514	90%
Loafing Lots	0	0%	0	
Forest	489,488	0.5%	489,488	0%
Residential	47,095,700	46%	235,478	90%
Total	101,811,573	100%	996,098	90%

Table G-18b. Required annual reductions in direct nonpoint sources in sub-watershed SC-40.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	49,099	0.5%	2,455	95%
Wildlife in Streams	64,258	0.7%	64,258	70%
Straight Pipes	9,386,925	99%	0	100%
Total	9,500,282	100%	66,713	99%

Table G-19a. Required annual reductions in nonpoint sources in sub-watershed SC-41.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	15,057	0%	75	90%
Pasture	3,227,914	8%	16,140	90%
Loafing Lots	0	0%	0	
Forest	795,481	2%	795,481	0%
Residential	34,483,070	90%	172,415	90%
Total	38,521,522	100%	984,111	90%

Table G-19b. Required annual reductions in direct nonpoint sources in sub-watershed SC-41.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	5,963	0.1%	298	95%
Wildlife in Streams	123,162	1%	123,162	70%
Straight Pipes	10,300,050	99%	0	100%
Total	10,429,176	100%	123,461	99%

Table G-20a. Required annual reductions in nonpoint sources in sub-watershed SC-42.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	9,094	0.1%	45	90%
Pasture	4,068,148	35%	20,341	90%
Loafing Lots	0	0%	0	
Forest	382,934	3%	382,934	0%
Residential	7,235,237	62%	36,176	90%
Total	11,695,413	100%	439,497	90%

Table G-20b. Required annual reductions in direct nonpoint sources in sub-watershed SC-42.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	29,817	1%	1,491	95%
Wildlife in Streams	65,608	3%	65,608	70%
Straight Pipes	2,388,735	96%	0	100%
Total	2,484,160	100%	67,098	99%

Table G-21a. Required annual reductions in nonpoint sources in sub-watershed SC-43.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	82,850	0.1%	414	90%
Pasture	28,972,611	40%	144,863	90%
Loafing Lots	0	0%	0	
Forest	672,971	0.9%	672,971	0%
Residential	42,950,661	59%	214,753	90%
Total	72,679,093	100%	1,033,001	90%

Table G-21b. Required annual reductions in direct nonpoint sources in sub-watershed SC-43.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	39,657	0.3%	1,983	95%
Wildlife in Streams	134,061	1%	134,061	70%
Straight Pipes	12,476,940	99%	0	100%
Total	12,650,657	100%	136,044	99%

Table G-22a. Required annual reductions in nonpoint sources in sub-watershed SC-46.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	15,018	0.1%	75	90%
Pasture	1,914,505	7%	9,573	90%
Loafing Lots	0	0%	0	
Forest	555,979	2%	555,979	0%
Residential	25,910,105	91%	129,550	90%
Total	28,395,607	100%	695,177	90%

Table G-22b. Required annual reductions in direct nonpoint sources in sub-watershed SC-46.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	8,349	0.1%	417	95%
Wildlife in Streams	93,667	1%	93,667	70%
Straight Pipes	8,590,680	99%	0	100%
Total	8,692,696	100%	94,084	99%

Table G-23a. Required annual reductions in nonpoint sources in sub-watershed SC-47.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	10,705	0.1%	54	90%
Pasture	6,983,169	75%	34,916	90%
Loafing Lots	0	0%	0	
Forest	191,615	2%	191,615	0%
Residential	2,121,372	23%	0	90%
Total	9,306,861	100%	226,584	90%

Table G-23b. Required annual reductions in direct nonpoint sources in sub-watershed SC-47.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	56,984	6%	2,849	95%
Wildlife in Streams	43,337	5%	43,337	70%
Straight Pipes	832,770	89%	0	100%
Total	933,091	100%	46,186	99%

Table G-24a. Required annual reductions in nonpoint sources in sub-watershed SC-48.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	63,937	0.3%	320	90%
Pasture	8,124,357	35%	40,622	90%
Loafing Lots	0	0%	0	
Forest	356,170	2%	356,170	0%
Residential	14,638,124	63%	73,191	90%
Total	23,182,588	100%	470,302	90%

Table G-24b. Required annual reductions in direct nonpoint sources in sub-watershed SC-48.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	49,695	2%	2,485	95%
Wildlife in Streams	54,930	2%	54,930	70%
Straight Pipes	2,235,330	96%	0	100%
Total	2,339,955	100%	57,414	99%

Table G-25a. Required annual reductions in nonpoint sources in sub-watershed SC-50.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	82,088	0.2%	410	90%
Pasture	16,585,496	42%	82,927	90%
Loafing Lots	0	0%	0	
Forest	440,960	1%	440,960	0%
Residential	22,106,574	56%	110,533	90%
Total	39,215,117	100%	634,830	90%

Table G-25b. Required annual reductions in direct nonpoint sources in sub-watershed SC-50.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	64,206	2%	3,210	95%
Wildlife in Streams	72,886	3%	72,886	70%
Straight Pipes	2,746,680	95%	0	100%
Total	2,883,772	100%	76,097	99%

Table G-26a. Required annual reductions in nonpoint sources in sub-watershed SC-51.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	7,367	0.1%	37	90%
Pasture	4,307,200	46%	21,536	90%
Loafing Lots	0	0%	0	
Forest	1,046,106	11%	1,046,106	0%
Residential	3,940,500	42%	19,702	90%
Total	9,301,172	100%	1,087,382	90%

Table G-26b. Required annual reductions in direct nonpoint sources in sub-watershed SC-51.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	38,762	6%	1,938	95%
Wildlife in Streams	57,322	9%	57,322	70%
Straight Pipes	555,180	85%	0	100%
Total	651,264	100%	59,260	99%

Table G-27a. Required annual reductions in nonpoint sources in sub-watershed SC-52.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	14,542	0.1%	73	90%
Pasture	4,221,408	43%	21,107	90%
Loafing Lots	0	0%	0	
Forest	242,146	2%	242,146	0%
Residential	5,382,141	55%	26,911	90%
Total	9,860,237	100%	290,236	90%

Table G-27b. Required annual reductions in direct nonpoint sources in sub-watershed SC-52.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	12,192	2%	610	95%
Wildlife in Streams	41,243	6%	41,243	70%
Straight Pipes	664,755	93%	0	100%
Total	718,190	100%	41,853	99%

Table G-28a. Required annual reductions in nonpoint sources in sub-watershed SC-54.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	45,550	0.3%	228	90%
Pasture	2,753,609	18%	13,768	90%
Loafing Lots	0	0%	0	
Forest	375,240	2%	375,240	0%
Residential	12,194,054	79%	60,970	90%
Total	15,368,454	100%	450,206	90%

Table G-28b. Required annual reductions in direct nonpoint sources in sub-watershed SC-54.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	19,381	0.9%	969	95%
Wildlife in Streams	63,626	3%	63,626	70%
Straight Pipes	2,016,180	96%	0	100%
Total	2,099,187	100%	64,595	99%

Table G-29a. Required annual reductions in nonpoint sources in sub-watershed SC-55.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	68,572	0.1%	343	90%
Pasture	11,646,431	11%	58,232	90%
Loafing Lots	0	0%	0	
Forest	887,050	0.9%	887,050	0%
Residential	90,665,642	88%	453,328	90%
Total	103,267,695	100%	1,398,952	90%

Table F-29b. Required annual reductions in direct nonpoint sources in sub-watershed SC-55.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	83,985	0.6%	4,199	95%
Wildlife in Streams	130,145	0.9%	130,145	70%
Straight Pipes	13,696,875	98%	0	100%
Total	13,911,004	100%	134,344	99%

Table G-30a. Required annual reductions in nonpoint sources in sub-watershed NFSL-1.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	721,315	1%	72,131	85%
Pasture	63,019,737	89%	6,301,975	85%
Loafing Lots	0	0%	0	
Forest	705,855	1.0%	705,855	0%
Residential	6,359,837	9%	635,984	85%
Total	70,806,743	100%	7,715,945	85%

Table G-30b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-1.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	183,673	52%	18,367	30%
Wildlife in Streams	167,963	48%	134,371	0%
Straight Pipes	0	0%	0	100%
Total	351,636	100%	152,738	17%

Table G-31a. Required annual reductions in nonpoint sources in sub-watershed NFSL-3.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	707,904	0.4%	70,790	85%
Pasture	164,310,832	96%	16,431,087	85%
Loafing Lots	0	0%	0	
Forest	2,213,118	1%	2,213,118	0%
Residential	3,899,234	2%	389,923	85%
Total	171,131,088	100%	19,104,919	85%

Table G-31b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-3.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	554,763	51%	55,476	30%
Wildlife in Streams	526,940	49%	421,552	0%
Straight Pipes	0	0%	0	100%
Total	1,081,703	100%	477,028	17%

Table G-32a. Required annual reductions in nonpoint sources in sub-watershed NFSL-4.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	1,444,387	1%	144,439	85%
Pasture	118,957,779	95%	11,895,781	85%
Loafing Lots	0	0%	0	
Forest	951,300	0.8%	951,300	0%
Residential	3,397,227	3%	339,723	85%
Total	124,750,692	100%	13,331,243	85%

Table G-32b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-4.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	268,221	56%	26,822	30%
Wildlife in Streams	212,470	44%	169,976	0%
Straight Pipes	0	0%	0	100%
Total	480,691	100%	196,798	17%

Table G-33a. Required annual reductions in nonpoint sources in sub-watershed NFSL-5.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	328,724	0.6%	32,872	85%
Pasture	53,818,062	95%	5,381,807	85%
Loafing Lots	0	0%	0	
Forest	860,870	2%	860,870	0%
Residential	1,524,188	3%	152,419	85%
Total	56,531,844	100%	6,427,969	85%

Table G-33b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-5.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	179,168	45%	17,917	30%
Wildlife in Streams	216,779	55%	173,424	0%
Straight Pipes	0	0%	0	100%
Total	395,947	100%	191,340	17%

Table G-34a. Required annual reductions in nonpoint sources in sub-watershed NFSL-7.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	1,326,683	1%	132,668	85%
Pasture	120,467,167	95%	12,046,720	85%
Loafing Lots	0	0%	0	
Forest	876,813	0.7%	876,813	0%
Residential	4,271,095	3%	427,110	85%
Total	126,941,759	100%	13,483,311	85%

Table G-34b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-7.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	197,190	52%	19,719	30%
Wildlife in Streams	180,454	48%	144,363	0%
Straight Pipes	0	0%	0	100%
Total	377,645	100%	164,082	17%

Table G-35a. Required annual reductions in nonpoint sources in sub-watershed NFSL-8.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	900,250	1.0%	90,025	85%
Pasture	87,561,222	93%	8,756,124	85%
Loafing Lots	0	0%	0	
Forest	457,843	0.5%	457,843	0%
Residential	5,735,508	6%	573,551	85%
Total	94,654,823	100%	9,877,543	85%

Table G-35b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-8.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	116,419	50%	11,642	30%
Wildlife in Streams	116,239	50%	92,992	0%
Straight Pipes	0	0%	0	100%
Total	232,659	100%	104,634	17%

Table G-36a. Required annual reductions in nonpoint sources in sub-watershed NFSL-9.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	392,120	0.7%	39,212	85%
Pasture	48,924,848	92%	4,892,486	85%
Loafing Lots	0	0%	0	
Forest	905,547	2%	905,547	0%
Residential	2,790,000	5%	279,000	85%
Total	53,012,516	100%	6,116,245	85%

Table G-36b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-9.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	167,837	43%	16,784	30%
Wildlife in Streams	224,828	57%	179,863	0%
Straight Pipes	0	0%	0	100%
Total	392,665	100%	196,646	17%

Table G-37a. Required annual reductions in nonpoint sources in sub-watershed NFSL-10.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	3,162,039	2%	316,204	85%
Pasture	155,710,474	95%	15,571,051	85%
Loafing Lots	0	0%	0	
Forest	1,154,542	0.7%	1,154,542	0%
Residential	3,980,714	2%	398,071	85%
Total	164,007,769	100%	17,439,869	85%

Table G-37b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-10.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	294,858	52%	29,486	30%
Wildlife in Streams	251,913	45%	201,530	0%
Straight Pipes	18,555	3%	0	100%
Total	565,325	100%	231,016	17%

Table G-38a. Required annual reductions in nonpoint sources in sub-watershed NFSL-12.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	1,996,955	1%	199,696	85%
Pasture	184,998,633	95%	18,499,868	85%
Loafing Lots	0	0%	0	
Forest	1,734,733	0.9%	1,734,733	0%
Residential	6,631,033	3%	663,103	85%
Total	195,361,354	100%	21,097,400	85%

Table G-38b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-12.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	264,842	45%	26,484	30%
Wildlife in Streams	328,629	55%	262,903	0%
Straight Pipes	0	0%	0	100%
Total	593,471	100%	289,387	17%

Table G-39a. Required annual reductions in nonpoint sources in sub-watershed NFSL-14.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	471,102	6%	47,110	85%
Pasture	6,839,810	89%	683,981	85%
Loafing Lots	0	0%	0	
Forest	76,982	1%	76,982	0%
Residential	308,052	4%	30,805	85%
Total	7,695,946	100%	838,878	85%

Table G-39b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-14.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	22,794	49%	2,279	30%
Wildlife in Streams	23,854	51%	19,083	0%
Straight Pipes	0	0%	0	100%
Total	46,648	100%	21,363	17%

Table G-40a. Required annual reductions in nonpoint sources in sub-watershed NFSL-16.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	3,069,148	2%	306,915	85%
Pasture	165,841,772	97%	16,584,181	85%
Loafing Lots	0	0%	0	
Forest	604,569	0.4%	604,569	0%
Residential	2,149,094	1%	214,909	85%
Total	171,664,583	100%	17,710,575	85%

Table G-40b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-16.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	198,052	55%	19,805	30%
Wildlife in Streams	164,375	45%	131,500	0%
Straight Pipes	0	0%	0	100%
Total	362,427	100%	151,305	17%

Table G-41a. Required annual reductions in nonpoint sources in sub-watershed NFSL-17.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	2,368,286	2%	236,829	85%
Pasture	135,283,712	95%	13,528,374	85%
Loafing Lots	0	0%	0	
Forest	304,546	0.2%	304,546	0%
Residential	3,758,906	3%	375,891	85%
Total	141,715,450	100%	14,445,640	85%

Table G-41b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-17.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	77,425	53%	7,743	30%
Wildlife in Streams	68,114	47%	54,491	0%
Straight Pipes	0	0%	0	100%
Total	145,539	100%	62,233	17%

Table G-42a. Required annual reductions in nonpoint sources in sub-watershed NFSL-18.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	2,948,861	1%	294,886	85%
Pasture	235,396,253	96%	23,539,631	85%
Loafing Lots	0	0%	0	
Forest	582,357	0.2%	582,357	0%
Residential	5,091,468	2%	509,147	85%
Total	244,018,940	100%	24,926,021	85%

Table G-42b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-18.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	348,529	69%	34,853	30%
Wildlife in Streams	157,091	31%	125,672	0%
Straight Pipes	0	0%	0	100%
Total	505,619	100%	160,525	17%

Table G-43a. Required annual reductions in nonpoint sources in sub-watershed NFSL-19.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	1,324,765	1%	132,476	85%
Pasture	102,172,582	97%	10,217,261	85%
Loafing Lots	0	0%	0	
Forest	248,981	0.2%	248,981	0%
Residential	2,113,183	2%	211,318	85%
Total	105,859,511	100%	10,810,037	85%

Table G-43b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-19.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	39,822	43%	3,982	30%
Wildlife in Streams	52,101	57%	41,681	0%
Straight Pipes	0	0%	0	100%
Total	91,924	100%	45,663	17%

Table G-44a. Required annual reductions in nonpoint sources in sub-watershed NFSL-20.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	272,438	0.4%	27,244	85%
Pasture	69,731,109	98%	6,973,113	85%
Loafing Lots	0	0%	0	
Forest	268,819	0.4%	268,819	0%
Residential	1,029,959	1%	102,996	85%
Total	71,302,324	100%	7,372,171	85%

Table G-44b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-20.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	139,544	65%	13,954	30%
Wildlife in Streams	73,811	35%	59,049	0%
Straight Pipes	0	0%	0	100%
Total	213,355	100%	73,003	17%

Table G-45a. Required annual reductions in nonpoint sources in sub-watershed NFSL-21.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	95,366	0.4%	9,537	85%
Pasture	20,871,841	97%	2,087,185	85%
Loafing Lots	0	0%	0	
Forest	108,234	0.5%	108,234	0%
Residential	379,349	2%	37,935	85%
Total	21,454,789	100%	2,242,890	85%

Table G-45b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-21.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	24,516	44%	2,452	30%
Wildlife in Streams	31,602	56%	25,281	0%
Straight Pipes	0	0%	0	100%
Total	56,118	100%	27,733	17%

Table G-46a. Required annual reductions in nonpoint sources in sub-watershed NFSL-22.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	1,214,050	4%	121,405	85%
Pasture	31,347,005	94%	3,134,701	85%
Loafing Lots	0	0%	0	
Forest	85,428	0.3%	85,428	0%
Residential	587,719	2%	58,772	85%
Total	33,234,202	100%	3,400,306	85%

Table G-46b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-22.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	31,142	56%	3,114	30%
Wildlife in Streams	24,932	44%	19,946	0%
Straight Pipes	0	0%	0	100%
Total	56,075	100%	23,060	17%

Table G-47a. Required annual reductions in nonpoint sources in sub-watershed NFSL-24.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	869,007	1%	86,901	85%
Pasture	58,608,553	96%	5,860,857	85%
Loafing Lots	0	0%	0	
Forest	334,473	0.5%	334,473	0%
Residential	1,023,431	2%	102,343	85%
Total	60,835,464	100%	6,384,573	85%

Table G-47b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-24.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	152,133	63%	15,213	30%
Wildlife in Streams	88,521	37%	70,817	0%
Straight Pipes	0	0%	0	100%
Total	240,655	100%	86,030	17%

Table G-48a. Required annual reductions in nonpoint sources in sub-watershed NFSL-26.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	577,587	0.8%	57,759	85%
Pasture	71,989,346	96%	7,198,936	85%
Loafing Lots	0	0%	0	
Forest	452,430	0.6%	452,430	0%
Residential	1,841,189	2%	184,119	85%
Total	74,860,552	100%	7,893,244	85%

Table G-48b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-26.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	120,594	56%	12,059	30%
Wildlife in Streams	76,401	35%	61,121	0%
Straight Pipes	19,431	9%	0	100%
Total	216,426	100%	73,180	17%

Table G-49a. Required annual reductions in nonpoint sources in sub-watershed NFSL-27.

Land Use	Current conditions load (x 10⁸ cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cropland	201,343	0.7%	20,134	85%
Pasture	28,633,444	96%	2,863,345	85%
Loafing Lots	0	0%	0	
Forest	275,252	0.9%	275,252	0%
Residential	660,987	2%	66,099	85%
Total	29,771,027	100%	3,224,831	85%

Table G-49b. Required annual reductions in direct nonpoint sources in sub-watershed NFSL-27.

Source	Current Conditions load (x 10⁸ cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10⁸ cfu/year)	Percent Reduction
Cattle in Streams	80,572	57%	8,057	30%
Wildlife in Streams	61,480	43%	49,184	0%
Straight Pipes	0	0%	0	100%
Total	142,052	100%	57,241	17%

Appendix H: Simulated Stream Flow Charts for TMDL Allocation Period

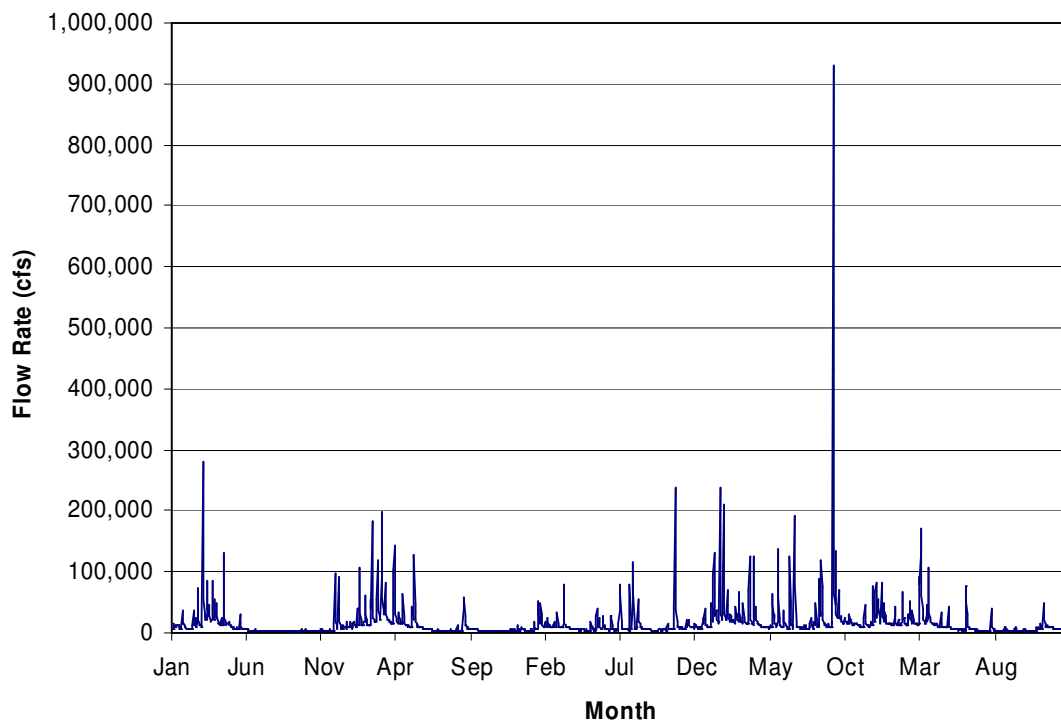


Figure H.1. Simulated stream flow for North Fork Shenandoah.

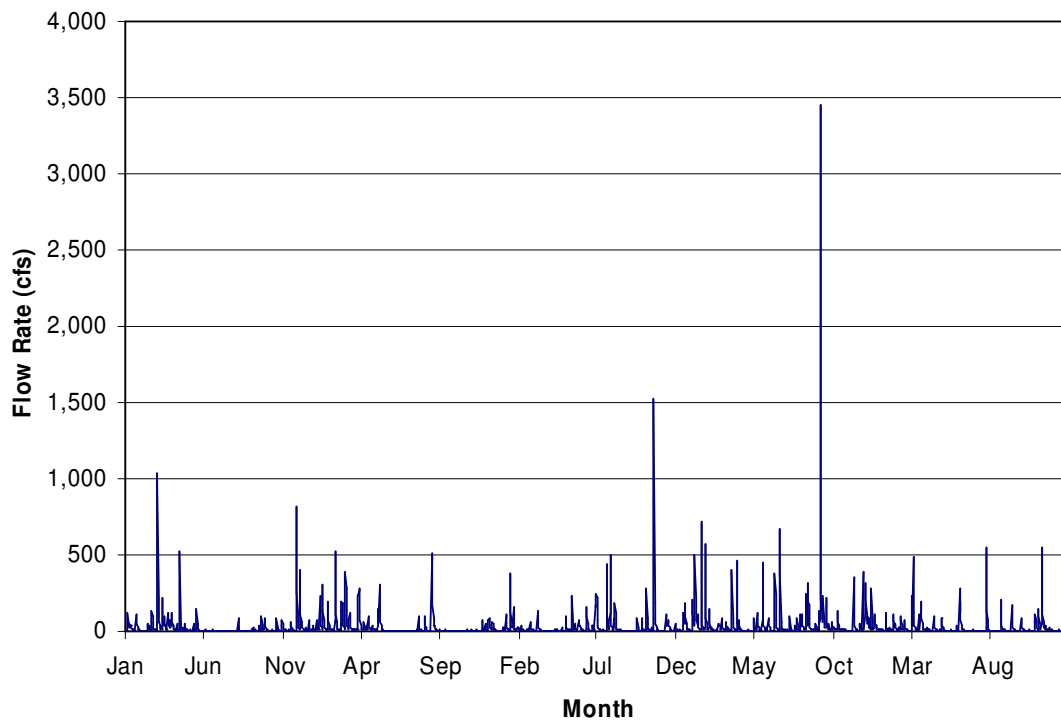


Figure H.2. Simulated stream flow for Stony Creek.

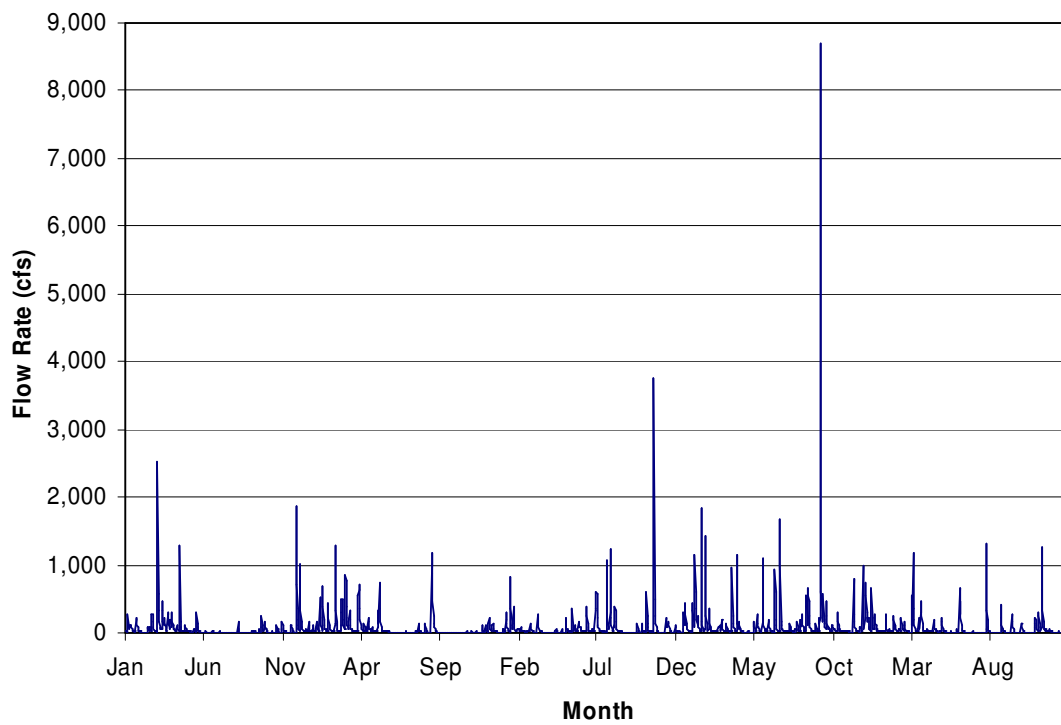


Figure H.3. Simulated stream flow for Mill Creek.

Appendix I: Observed Fecal Coliform Concentrations and Antecedent Rainfall

This appendix presents the observed fecal coliform concentrations and antecedent rainfall for the six stations that caused the impairment listings (Table I.1).

Table I.1. Observed fecal coliform concentrations and antecedent rainfall for the listing stations for Pigg River and Old Womans Creek.

Station	Date	Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 days (inches)
Stony Creek			
1BSTY001.22	12/2/1997	100	0.0
1BSTY001.22	11/5/1997	500	1.0
1BSTY001.22	10/6/1997	100	0.0
1BSTY001.22	9/8/1997	100	0.0
1BSTY001.22	8/5/1997	800	0.3
1BSTY001.22	7/10/1997	200	0.3
1BSTY001.22	6/5/1997	600	2.5
1BSTY001.22	5/29/1997	100	0.6
1BSTY001.22	4/3/1997	100	0.5
1BSTY001.22	2/4/1997	100	0.3
1BSTY001.22	1/7/1997	100	0.1
1BSTY001.22	12/3/1996	300	2.0
1BSTY001.22	11/12/1996	200	1.5
1BSTY001.22	10/2/1996	1200	0.8
1BSTY001.22	9/3/1996	200	1.0
1BSTY001.22	8/5/1996	500	1.3
1BSTY001.22	7/2/1996	200	0.5
1BSTY001.22	6/12/1996	500	2.4
1BSTY001.22	5/8/1996	200	1.3
1BSTY001.22	4/2/1996	100	1.8
1BSTY001.22	3/5/1996	100	0.0
1BSTY001.22	2/22/1996	200	0.6
1BSTY001.22	1/3/1996	500	1.2
1BSTY001.22	12/5/1995	100	0.1
1BSTY001.22	11/2/1995	900	0.2
1BSTY001.22	10/4/1995	2900	0.3
1BSTY001.22	9/18/1995	200	1.4
1BSTY001.22	8/3/1995	2300	1.1
1BSTY001.22	7/6/1995	600	0.7
1BSTY001.22	6/6/1995	500	0.1
1BSTY001.22	5/8/1995	2300	0.3
1BSTY001.22	4/4/1995	100	0.0
1BSTY001.22	3/6/1995	100	0.1
1BSTY001.22	2/8/1995	100	0.3
1BSTY001.22	1/4/1995	100	0.4
1BSTY001.22	12/5/1994	100	0.8

Station	Date	Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 days (inches)
1BSTY001.22	11/2/1994	100	0.3
1BSTY001.22	10/11/1994	100	0.0
1BSTY001.22	9/7/1994	100	0.1
1BSTY001.22	8/10/1994	600	0.2
1BSTY001.22	7/6/1994	100	0.1
1BSTY001.22	6/23/1994	300	0.2
1BSTY001.22	5/3/1994	100	0.8
1BSTY001.22	4/5/1994	100	0.1
1BSTY001.22	2/2/1994	100	0.8
1BSTY001.22	1/25/1994	300	0.1
1BSTY001.22	12/2/1993	100	3.1
1BSTY001.22	11/16/1993	100	0.2
1BSTY001.22	10/7/1993	100	0.0
1BSTY001.22	9/2/1993	100	1.0
1BSTY001.22	8/5/1993	1100	0.0
1BSTY001.22	7/7/1993	8000	0.7
1BSTY001.22	6/3/1993	600	0.1
1BSTY001.22	5/11/1993	100	0.0
1BSTY001.22	4/6/1993	300	0.6
1BSTY001.22	3/9/1993	100	3.0
1BSTY001.22	2/4/1993	100	0.0
1BSTY001.22	1/14/1993	200	0.5
Mill Creek			
1BMIL002.20	10/2/1997	300	1.1
1BMIL002.20	7/16/1997	400	0.1
1BMIL002.20	4/2/1997	100	0.5
1BMIL002.20	1/13/1997	100	0.6
1BMIL002.20	11/18/1996	400	0.1
1BMIL002.20	7/30/1996	8000	1.1
1BMIL002.20	4/17/1996	400	0.5
1BMIL002.20	2/8/1996	300	0.4
1BMIL002.20	11/27/1995	100	0.1
1BMIL002.20	8/30/1995	900	0
1BMIL002.20	5/31/1995	1500	0.94
1BMIL002.20	1/18/1995	300	1.6
1BMIL002.20	11/14/1994	100	0.4
1BMIL002.20	8/2/1994	400	0
1BMIL002.20	2/23/1994	3400	1.4
1BMIL002.20	1/5/1994	100	0.5
1BMIL002.20	7/22/1993	400	0.3
1BMIL002.20	4/29/1993	300	0.5
1BMIL002.20	1/25/1993	100	0.9
North Fork Shenandoah River			
1BNFS054.75	12/2/1997	100	0
1BNFS054.75	11/5/1997	100	1
1BNFS054.75	10/6/1997	100	0

Station	Date	Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 days (inches)
1BNFS054.75	9/8/1997	100	0
1BNFS054.75	8/5/1997	100	0.3
1BNFS054.75	7/10/1997	100	0.3
1BNFS054.75	6/5/1997	700	2.5
1BNFS054.75	5/29/1997	100	0.6
1BNFS054.75	4/3/1997	100	0.5
1BNFS054.75	2/4/1997	100	0.3
1BNFS054.75	1/7/1997	100	0.1
1BNFS054.75	12/3/1996	700	2
1BNFS054.75	11/12/1996	600	1.5
1BNFS054.75	10/2/1996	200	0.8
1BNFS054.75	9/3/1996	100	1
1BNFS054.75	8/5/1996	1700	1.3
1BNFS054.75	7/2/1996	100	0.5
1BNFS054.75	6/12/1996	100	2.4
1BNFS054.75	5/8/1996	600	1.3
1BNFS054.75	4/2/1996	2200	1.8
1BNFS054.75	3/5/1996	100	0
1BNFS054.75	2/22/1996	100	0.6
1BNFS054.75	1/3/1996	700	1.2
1BNFS054.75	12/5/1995	100	0.1
1BNFS054.75	11/2/1995	100	0.2
1BNFS054.75	10/4/1995	100	0.3
1BNFS054.75	9/18/1995	400	1.35
1BNFS054.75	8/3/1995	100	1.1
1BNFS054.75	7/6/1995	500	0.7
1BNFS054.75	6/6/1995	100	0.1
1BNFS054.75	5/8/1995	100	0.3
1BNFS054.75	4/4/1995	100	0
1BNFS054.75	3/6/1995	100	0.1
1BNFS054.75	2/8/1995	100	0.3
1BNFS054.75	1/4/1995	100	0.4
1BNFS054.75	12/5/1994	100	0.8
1BNFS054.75	11/2/1994	200	0.3
1BNFS054.75	10/11/1994	100	0
1BNFS054.75	9/7/1994	100	0.1
1BNFS054.75	8/10/1994	200	0.2
1BNFS054.75	7/6/1994	100	0.1
1BNFS054.75	6/23/1994	400	0.2
1BNFS054.75	5/3/1994	300	0.8
1BNFS054.75	4/5/1994	100	0.1
1BNFS054.75	2/2/1994	100	0.8
1BNFS054.75	1/25/1994	3900	0.1
1BNFS054.75	12/2/1993	1000	3.1
1BNFS054.75	11/16/1993	100	0.2
1BNFS054.75	10/7/1993	100	0

Station	Date	Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 days (inches)
1BNFS054.75	9/2/1993	100	1
1BNFS054.75	8/5/1993	100	0
1BNFS054.75	7/7/1993	500	0.7
1BNFS054.75	6/3/1993	100	0.1
1BNFS054.75	5/11/1993	200	0
1BNFS054.75	4/6/1993	200	0.6
1BNFS054.75	3/9/1993	100	3
1BNFS054.75	2/4/1993	100	0
1BNFS054.75	1/14/1993	400	0.5

Appendix J: Scenarios for Fivefold Increase in Permitted Discharge Flow

To allow for future growth, a scenarios were created for Mill Creek, Stony Creek, and North Fork of the Shenandoah River in which the point source flows were increased by a factor of 5, while retaining the 126 cfu/100 mL limit on *E. coli* bacteria. This effectively increased the WLA by a factor of 5. This scenario was also applied to the <1% allowance for future conditions in watersheds currently without permitted point sources. Figures J.1-J.3 display the results for the impaired watersheds. The TMDL equations that would represent this situation are included in Table J.1.

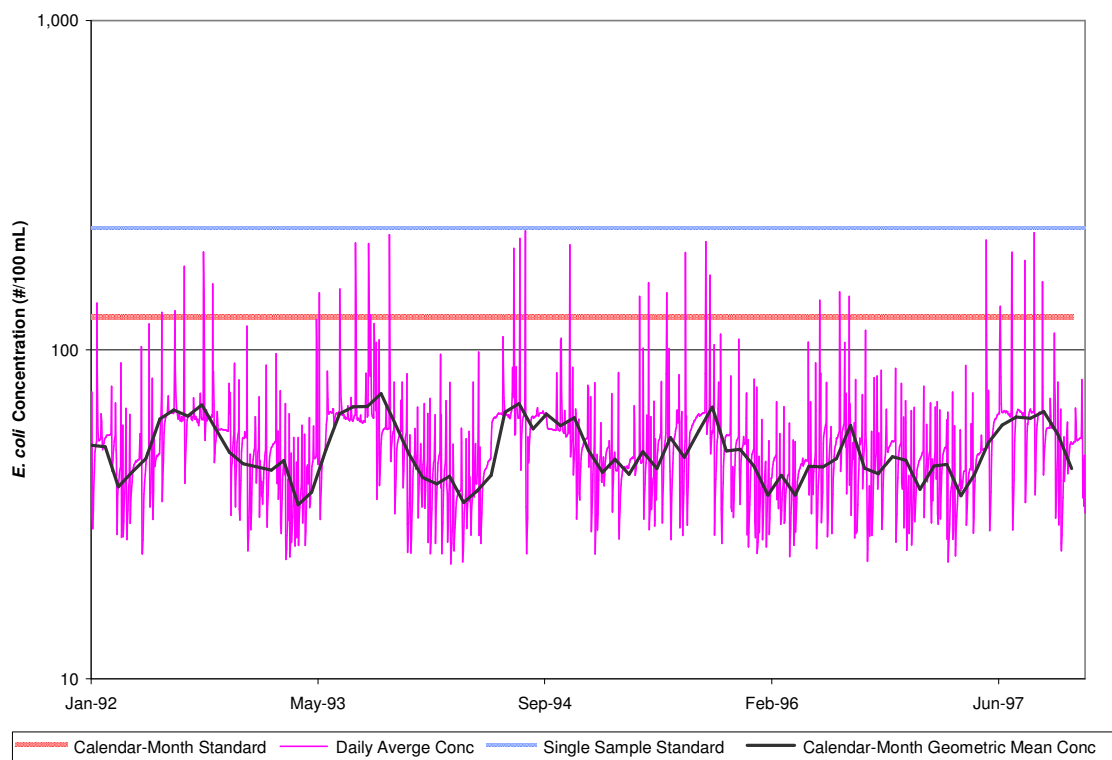


Figure J.1. Fivefold Increase Scenario for Mill Creek

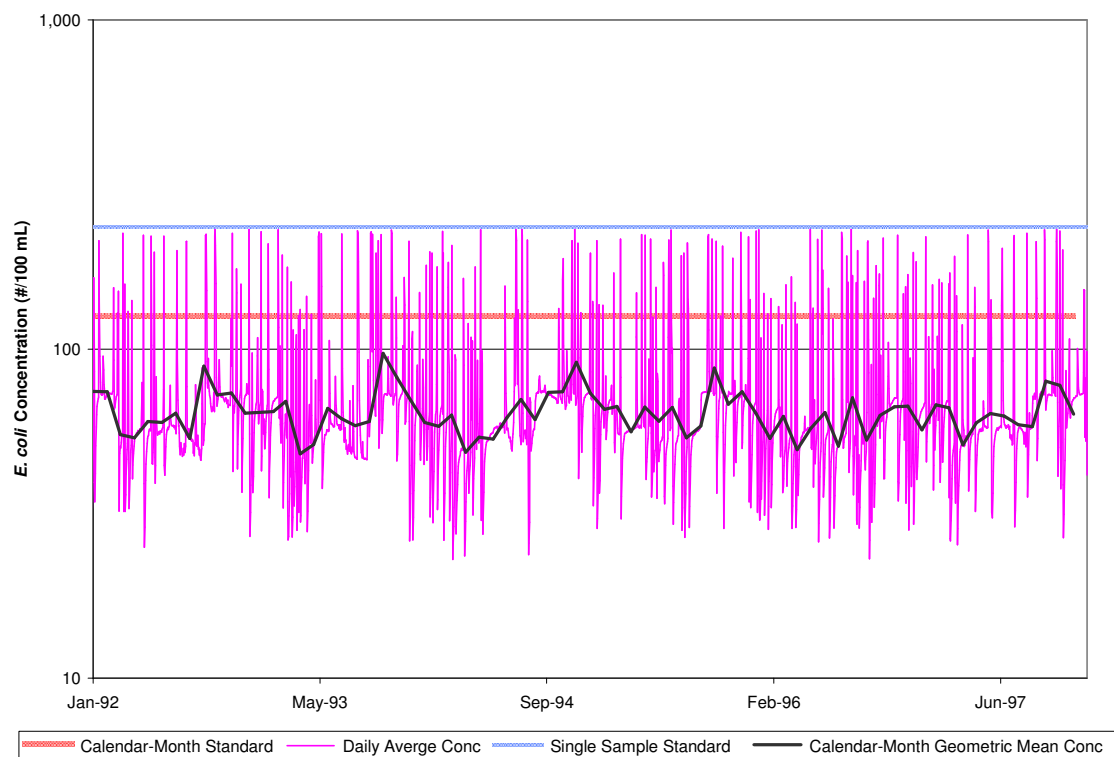


Figure J.2. Fivefold Increase Scenario for Stony Creek

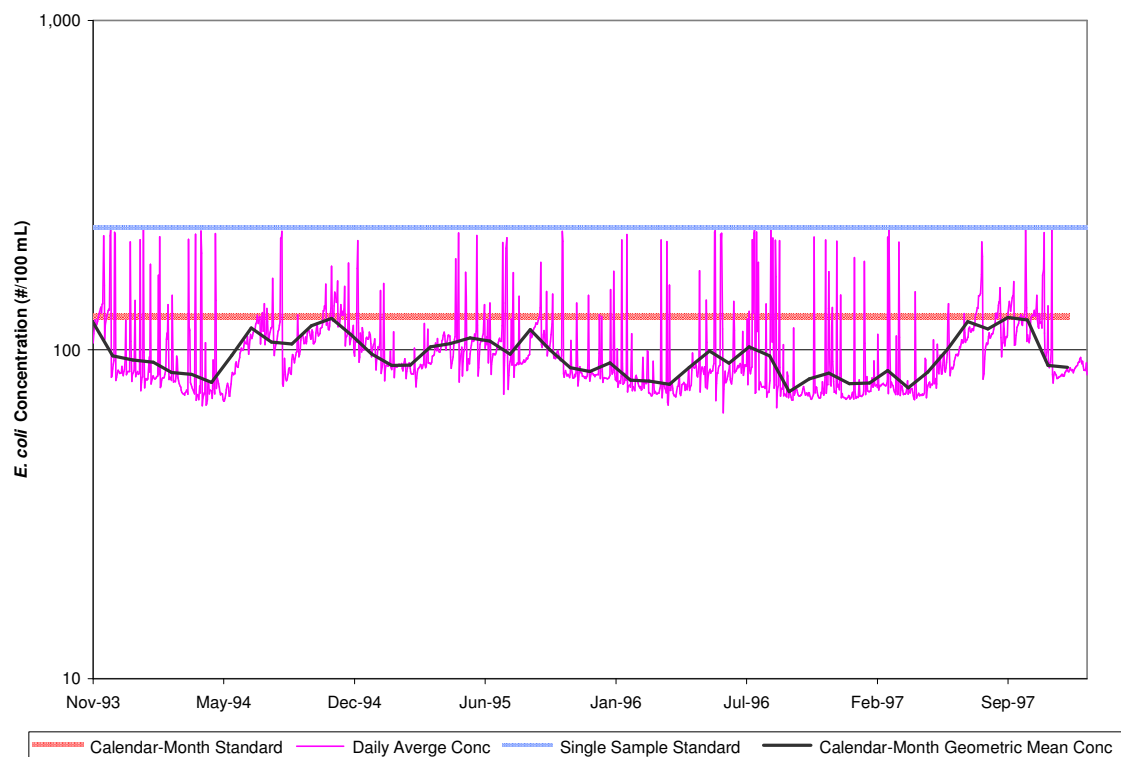


Figure J.3. Fivefold Increase Scenario for North Fork of the Shenandoah River.

Table J.1. Average annual *E.coli* loadings (cfu/yr) at the watershed outlet for the Mill Creek, Stony Creek, and the North Fork of the Shenandoah River watersheds under the fivefold WLA increase scenario.

Watershed	WLA	LA	MOS*	TMDL
Mill Creek	0.05×10^{12}	$1,988 \times 10^{12}$	--	$1,988.05 \times 10^{12}$
Stony Creek	22.1×10^{12}	$4,210 \times 10^{12}$	--	$4,231.1 \times 10^{12}$
North Fork of the Shenandoah River	29.6×10^{12}	$21,734 \times 10^{12}$	--	$21,764 \times 10^{12}$

*Implicit MOS

As can be seen from Figures J.1-J.3, the new scenario results in no violations of the single sample or geometric mean standard. Therefore, it is assumed that future growth in point source dischargers with a consistent permitted bacteria concentration of 126 cfu/100 mL *E. coli* will not cause additional violations of the water quality standards.